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BRIEF COMMUNICATION

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EFFECTS OF CAFFEINE AND THEOPHYLLINE ON FOOD UTILISATION AND EMERGENCE IN *DANAUS CHRYSIPPUS* L. (LEPIDOPTERA: DANIDAE)

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(*Received 22 June 1979*)

Final instar larvae of *Danaus chrysippus* L. (Lepidoptera : Danidae) were fed on *Calotropis gigantea* R. Br. leaf soaked in distilled water, 0.1, 0.2, 0.3, 0.4 and 0.5% caffeine and theophylline solutions. Aqueous caffeine or theophylline solutions at a concentration of 0.5% induced 64 or 43% larval mortality and 100% pupal mortality. In the theophylline series rates of feeding and assimilation progressively decreased with increasing concentration. Such a trend was apparent only in the groups feeding less than 0.4% caffeine treated leaf. Rate and efficiency of conversion of the larvae were significantly affected by these toxins. Assimilation efficiency of the larvae receiving 0.5% caffeine treated leaf was significantly higher than that of those receiving distilled water treated leaf. But the efficiency of the larva was not significantly altered by theophylline. Caffeine and theophylline treatment also lead to failure of metamorphosis.

(*Key words: Danaus chrysippus*, **mortality, food utilisation and emergence, caffeine and theophylline effects**)

INTRODUCTION

To discourage herbivority, plants have developed a variety of secondary plant substances which are occasionally toxic to consumer species (PRICE, 1975). Plant toxins are usually neutralised by consumer animals. Such toxins which cannot be fully neutralisd or can only be partly neutralised may considerably influence food consumption and utilisation in insects (KASTING & MCGINNIS, 1963; MATHAVAN & BHASKARAN, 1975). Insects are preferable for toxicity studies, since they have microsomal metabolism similar to that of mammals (WILKINSON & BRATSTEN, 1972). Little is known about the effect of plant toxins like caffeine and theophylline on food consumption and utilisation in insects. The present paper reports on the influence of caffeine and theophylline on the energy budget of the monarch butterfly, *Danaus chrysippus*.

MATERIALS AND METHODS

Calotropis gigantea leaf was cut into bits and soaked in distilled water (control), 0.1, 0.2, 0.3, 0.4 and 0.5% aqueous solutions of caffeine and theophylline for 1 hr. Solution adhering to the leaf surface was removed with the help of filter paper. Freshly moulted final instar larvae of *D. chrysippus* were individually fed *ad libitum* on weighed quantity of leaf treated as above. Food remains and faeces were collected every day before feeding. Samples of food, faeces, intial and terminal larvae were dried at 80°C to weight constancy. Food consumption was estimated following the gravimetric method of WALDBAUER (1968). Growth was estimated by subtracting the initial dry weight of the larva from that of terminal larva. Test individuals were maintained at constant laboratory conditions of 30 ± 1°C, 80 ± 10% rh and 10 hr photoperiod. Caloric contents of food, faeces, initial and terminal larva were estimated in a Parr 1411 semi-micro bomb calorimeter. Applying the caloric values, data obtained in dry weight were converted into calorie.

The scheme of energy budget followed in the present study is the IBP formula of PETRUSEWICZ & MACFADYEN (1970) represented as:

$$C = P + R + (F + U)$$

where C is the food energy consumed. P the growth (conversion), R energy spent on metabolism and F + U energy loss via faeces including nitrogenous excretory products; it has been described in detail elsewhere (MUTHUKIRSHNAN et al., 1978).

RESULTS

Larvae fed on leaf bits treated with distilled water passed through the final instar in 3 days. Consumption of leaf treated with toxins, resulted in the extension of the instar duration; it was 5 days in the group receiving 0.5% caffeine treated leaf and 4 days in the groups receiving 0.3, 0.4 and 0.5% theophylline or 0.2, 0.3 and 0.4% caffeine treated leaf. However, there was no difference between the instar duration of the larvae fed on 0.1% caffeine, 0.1, 0.2% theophylline or distilled water treated leaf.

Larval mortality was as high as 64% in the group feeding 0.5% caffeine treated leaf compared with 43% in that feeding 0.5% theophylline treated leaf (Table 1). About 20, 30 and 45% of the pharate pupae belonging to 0.3, 0.4 and 0.5% caffeine groups could not complete pupation and died as half pupa. All the pupae belonging to 0.4 and 0.5% caffeine or theophylline group died on the 3rd or 4th day of pupation. Death was preceded by tanning of the pupa. Pupae belonging to the distilled water group remained light green in colour till emergence. Briefly, caffeine proved to be more toxic than theophylline at any tested concentration (Table 1).

Table 2 presents data on food consumption, assimilation and production in terms of gcal/larva during final instar. Food consumption in the distilled water group amounted to 2671 gcal compared with 1981 or 2796 gcal in the group receiving 0.5% theophylline or caffeine treated leaf;

TABLE 1. Larval and pupal mortality of *Danaus chrysippus* as function of caffeine and theophylline concentration.

	Concentration (%)	Larval mortality (%)	Pupal mortality (%)
Control*		3.5	5.5
Caffeine	0.1	22.2	14.3
	0.2	31.6	30.0
	0.3	54.5	71.3
	0.4	61.5	100.0
	0.5	63.6	100.0
Theophylline	0.1	18.2	24.9
	0.2	20.0	33.3
	0.3	33.3	66.6
	0.4	39.9	100.0
	0.5	42.8	100.0

*Distilled water

barring the individuals in 0.5% caffeine group, larvae feeding toxin treated leaf assimilated comparatively less food than those in the control group. For instance, larva receiving 0.3% caffeine or theophylline treated leaf, assimilated 1159 or 1115 gcal whereas that in the control group as much as 1538 gcal. Feed energy converted into body tissue remarkably decreased in the larvae fed on toxin treated leaves; it was 740 gcal in the group; from this high value, it decreased to 356 or 328 gcal in the group fed on 0.5% caffeine or theophylline treated leaf.

Trends obtined for rates of feeding, assimilation and production of the larvae belonging to the three series are shown in Fig. 1. Following facts are obvious: 1. Test individuals in the control series exhibited the highest feeding rate (2389 gcal/g

TABLE 2. Effects of caffeine and theophylline on consumption (C), assimilation (A) and conversion (P) in the final instar larva of *Danaus chrysippus*. Each value (mean ± SD) represents the average performance of 10 or more larvae. Values are expressed in gcal/larva.

	Concentration (%)	C	A	P
Control*		2671.0 ± 329.2	1538.0 ± 163.5	739.7 ± 112.8
Caffeine	0.1	2161.9 ± 246.1	1265.7 ± 189.8	538.8 ± 48.2
	0.2	2020.5 ± 137.1	1231.3 ± 244.4	434.6 ± 45.1
	0.3	1847.5 ± 204.6	1158.9 ± 171.3	371.3 ± 46.2
	0.4	2648.0 ± 399.7	1188.7 ± 186.2	331.9 ± 29.3
	0.5	2769.1 ± 474.4	1979.2 ± 309.5	356.0 ± 46.6
Theophylline	0.1	2128.9 ± 247.7	1207.3 ± 216.2	526.3 ± 62.4
	0.2	2051.7 ± 383.5	1151.4 ± 208.3	511.9 ± 73.7
	0.3	2025.4 ± 400.9	1114.8 ± 310.8	442.7 ± 74.7
	0.4	2078.3 ± 509.6	1124.1 ± 268.0	393.8 ± 86.4
	0.5	1980.6 ± 237.6	1144.7 ± 265.9	327.8 ± 27.5

*Distilled water

live insect/day) and those feeding 0.5% theophylline treated leaf the least rate (1700 gcal/g/day); 2. whereas the theophylline series displayed a continuous decrease in the groups feeding only upto 0.3% caffeine treated leaf; 3. assimilation rate of the larvae feeding 0.5% caffeine treated leaf (1389 gcal/g/day) was more or less equivalent to that in the distilled water group; and 4. production rate of the larvae receiving caffeine or theophylline treated leaf was less than that of the control series.

Fig. 2 shows assimilation and net conversion efficiency values (%) of the larae as functions of caffeine and theophylline concentrations. Mean efficiency values obtained for the different groups in the caffeine and theophylline series were compared with that obtained for the control group following BAILEY (1965). Assimilation efficiency of the larvae belonging to caffeine series was higher than that of those in the control series. The increase in the assimilation efficiency of the larvae feeding 0.5% caffeine treated leaf (70%) was statistically significant over that of those feeding distilled water treated leaf (58%). However, theophylline failed to evoke any remarkable change in the assimilation efficiency of the larvae. Net conversion efficiency of the larvae belonging to caffeine and theophylline series was less than that of those in the distilled water group. The efficiency was 48% in the distilled water group compared with 32 or 18% in the group feeding 0.3 or 0.5% caffeine treated leaf. Corresponding values for the groups receiving 0,3 and 0.5% theophylline treated leaf were 40 and 29% respectively. Differences in the efficiency of the larvae in the caffeine groups (0.2% group onwards) and that of those in the

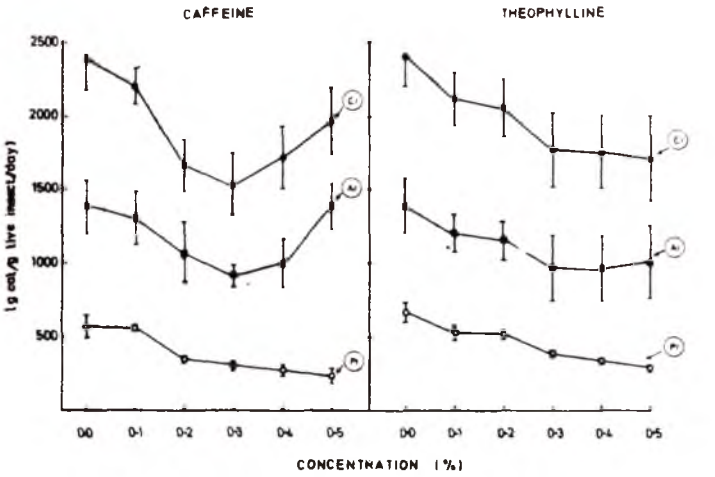

Fig. 1. Rates of food consumption (Cr), Assimilation (Ar) and Production (Pr) as functions of caffeine and theophylline concentrations in the final instar larva of *Danaus chrysippus*. Each value represents the average performance of 10 or more larvae. Vertical lines represent SD.

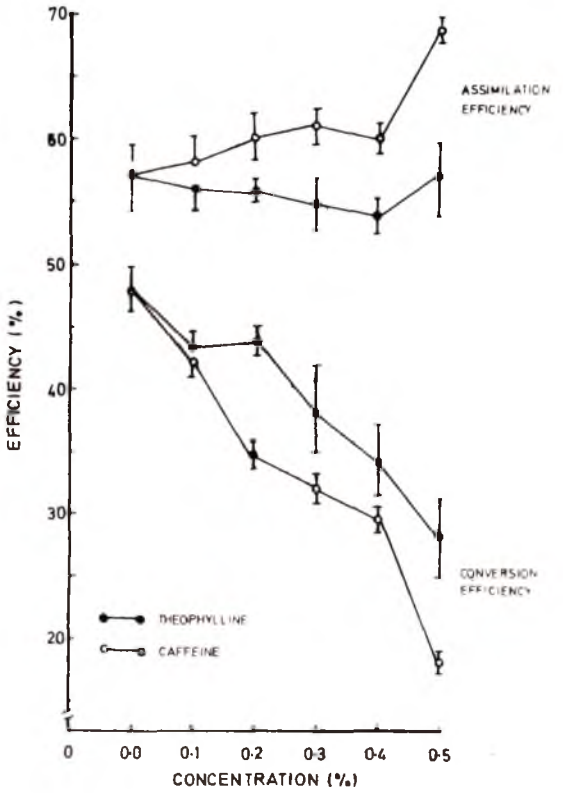

Fig. 2. Efficiencies of Assimilation and Production in the final instar larva of *Danaus chrysippus* as functions of caffeine and theophylline concentrations. Each value represents the average performance of 10 or more larvae. Vertical lines represent SD.

control group were statistically significant ($p<0.05$, 0.002, 0.002, and 0.001 for 0.2, 0.3, 0.4 and 0.5% groups *vs* control group, in = 20).

DISCUSSION

Retardation of growth, incomplete pupation and inhibition of adult emergence leading to mortality of pupa are the toxic effects of caffeine and theophylline on *D. chrysippus* larva. A significant decrease in the rate (Fig. 1) and efficiency (Fig. 2) of conversion of food into body tissue led to the retardation of growth and production of 'mini' pupa. Mean live weight of the pupa formed by the larva feeding 0.5% caffeine or theophylline treated leaf was 375 or 413 mg. Similar result has been reported for larva of the housefly *Musca domestica* (SRINIVASAN & KESAVAN, 1977); live weight of the larva reared on milk pads soaked in 0.2% caffeine was less than that reared on milk pads free from caffeine. Holometabolous insects accumulate substantial nutrient reserves during the final larval stage, which are chiefly deposited as fat and glycogen in their fat body (GILBERT, 1964; WYATT, 1972). Caffeine considerably affects the synthesis of stored products and nucleic acids (PUTRAMENT et al., 1972; ZUK & SWIETLINSKA, 1973; LAUX DAVID & KLESIUS, 1973). Hence, retardation of growth and formation of 'mini' pupa from the larva feeding caffeine or theophylline treated leaf are due to the effect of these toxins on the synthesis of stored products and macromolecules.

MUTHAPARANAM (1976) found that *D. chrysippus* larva receiving 100 mg *C. gigantea* leaf/day exhibits a conversion rate as low as 37 gcal/g live insect/day and yet manages to successfully complete pupation and emerge subsequently. Despite a far higher conversion rate (239 gcal/g/day) exhibited by the larvae in 0.3, 0.4 and 0.5% caffeine groups about 20, 30 and 45% of the pharate pupae failed to complete pupation and died as half pupa. Caffeine has been shown to enhance the activity of microsomal oxidase (MITTOMA *et al.*, 1969), exert a considerable delay in pupariation and produce lesions which are typical of hormone imbalance (YU & TERRIERE, 1971). Disruption of the normal activity of the brain leading to the upset of hormonal balance and/or changes in the activity of microsomal oxidase are likely to be responsible for the formation of half pupa. BLAUSTIN & SCHNEIDRMAN (1960) and MCDANIEL & BERRY (1974) found that upset of hormonal balance is responsible for half pupation and inhibition of adult emergence in the moth *Callosomia prometha* and *Hyalophora cecropia*. CYMBROWSKI & KRYSPIN (1975) found that reserpine, a neuroleptic substance, affects growth, developmet and metamorphosis of larvae of the waxmoth *Galleria mellonella* by inhibiting the activity of the neurosecretory cells of pars intercerebralis and accumulating neurosecretory substances.

Assimilation efficiency of the larvae feeding 0.5% caffeine treated leaf was (70%) significantly higher than that of those feeding distilled water treated leaf (58%). Cyclic AMP or adenyl cyclase – phosphodiesterase system plays an important role in the digestive function (WHITMORE et al., 1973). In the silkworm *Bombyx mori* MORISHIMA (1973) found that caffeine increases the level of cyclic AMP by inhibiting cyclic AMP phosphodiesterase activity. Cyclic AMP causes a large sudden increase in the secretion rate of isolated salivary glands of *Calliphora erythrocephala* (BERRIDGE, 1970). It increases also the permeability of mucosal membrane (ORLOFF & HANDLER, 1967). Therefore, it is probable that caffeine by decreasing the cyclic AMP phosphodiesterase activity and thereby raising the cyclic AMP level not only increases the rate of secretion of digestive glands but also the rate of absorption of the digested food.

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MONTHLY VARIATION IN THE DENSITY OF SOIL MICROARTHROPODS IN RELATION TO SOME CLIMATIC AND EDAPHIC FACTORS

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Population fluctuation of soil microarthropods in a wasteland of Santiniketan was studied in relation to some climatic and edaphic factors for two years. Soil microarthropods including the two major groups viz., Cryptostigmata and Collembola showed two peaks, a pronounced peak during postmonsoon period (September-October) and a less pronounced one during premonsoon period (May-June). Of the various factors studied moisture content and temperature of the soil, rainfall of the previous month, mean monthly relative humidity and air temperature at the time of sampling showed a significant positive correlation with the total microarthropod population. Collembolan population was found to have significant positive correlation with the mean monthly RH, air temperature and with the moisture content of the soil, whereas only mean monthly RH and moisture content of the soil had a significant positive correlation with the cryptostigmatid mites. Contrary to these pH of the soil showed significant negative correlation with Cryptostigmata, Collembola and with microarthropod population in general. Moisture content of the soil was considered to be the most important single factor responsible for the population fluctuation of the microarthropods inhabiting soil.

(*Key words:* **population fluctuation, soil microarthropods, Santiniketan-India, Cryptostigmata, Collembola, climatic and edaphic factors**)

INTRODUCTION

Climate of the soil, to a large extent, is dependent on the atmospheric climatic conditions. These, not only have direct influence on the nature of the soil but also determine vegetational pattern as well as soil microfauna and microflora. Fluctuations of such abiotic factors may often cause changes in the population density of microarthropods inhabiting surface soil. Present paper deals with the monthly variations in the density of soil microarthropods *vis-a-vis* some climatic and edaphic factors in a wasteland at Santiniketan. An account of the climate and physicochemical properties of the soil of Santiniketan and adjacent area is being published elsewhere (BHATTACHARYA, in Press).

MATERIAL AND METHODS

A plot of 5m × 5m in an uncultivated wasteland tedwast was selected for the purpose of present investigation since it was subjected to least human interference. The site had a dense cover of surface vegetation during rainy season. The dominant flora of the area was a creeper, *Antigonon leptopus*. Soil samples were taken mostly on the 4th day of the month, always between 16.00 hr to 17.00 hr during May 1969 to July 1971. No sampling could be done in the month of May and June 1970. During each sampling occassion six samples, 5 cm × 5 cm

× 5 cm. were taken from the soil surface for the study of microarthoropods and four for the physico-chemical analysis of the soil.

Microarthropods were extracted with the help of 'Tullgren funnels'. Moisture content of the soil was determined by using a torsion balance moisture meter. Determination of pH was with the help of a glass electrode pH meter; organic carbon was estimated by WALKLEY & BLACK'S rapid titration method and conductivity of the soil was measured using a Wheatstone bridge. Temperature of soil was measured by inserting thermometer at a depth of 5 cm in soil. Simultaneous to this air temperature was also recorded. Meteorological data, viz., daily maximum and minimum temperature, relative humidity and rainfall were obtained from the nearby "Sferics observatory" at Sriniketan. Simple correlation between different factors and the population size of microarthropods in toto, cryptostigmatid mites and Collembola were drawn separately and their statistical significance was determined.

RESULTS AND DISCUSSION

Different climatic and edaphic factors showed considerable variation from time to time (Figs. 1 & 2). In the present investigation two peaks have been observed with regard to the population of total microarthropods and the two major groups viz., Cryptostigmata and Collembola (Fig. 3). One of these peaks was much pronounced and observed during post-monsoon period (September–October) and the other, a less distinct one was noted during late summer or pre-monsoon (May-June) period. The population density maintained a low level between December to April. The post-monsoon peak tallies with the observation of MUKHARJI & SINGH (1970), CHOUDHURI & ROY (1971 a, b, 1972) and PRABHOO (1976), who worked in different parts of India. An inconsistancy, however, is noted with respect to the time of the second peak. None of these workers observed a peak during the late summer or pre-monsoon months but LOOT & RYKE (1966) working in Tropical Africa found a peak during late summer. Minimum population during winter tallies with the findings of LOOTS & RYKE (1966) and CHOUDHURI & ROY (1971 a).

Fluctuation of the density of soil microarthropods seem to involve several environmental factors. Of the various factors studied (Table 1), moisture content and the temperature of the soil, rainfall of the

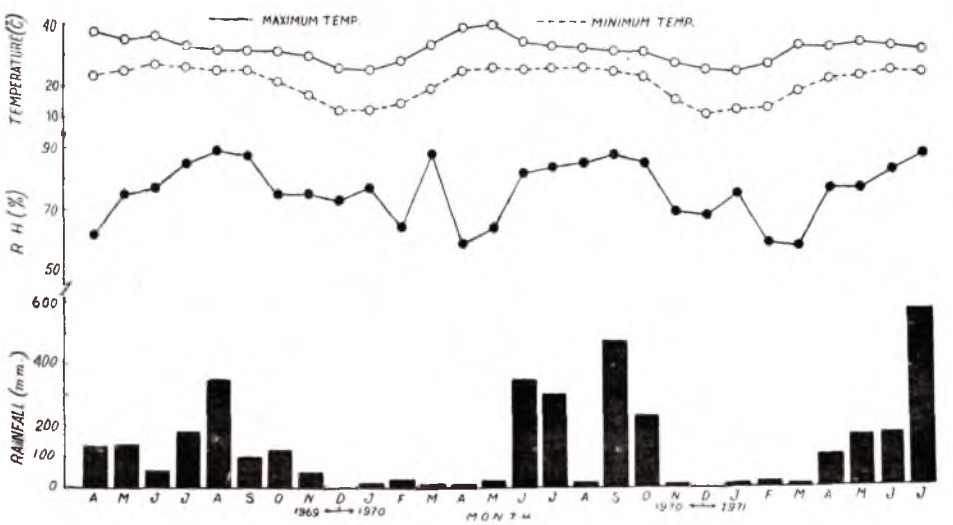

Fig. 1. Monthly rainfall, relative humidity and temperature at Santiniketan during period of investigation.

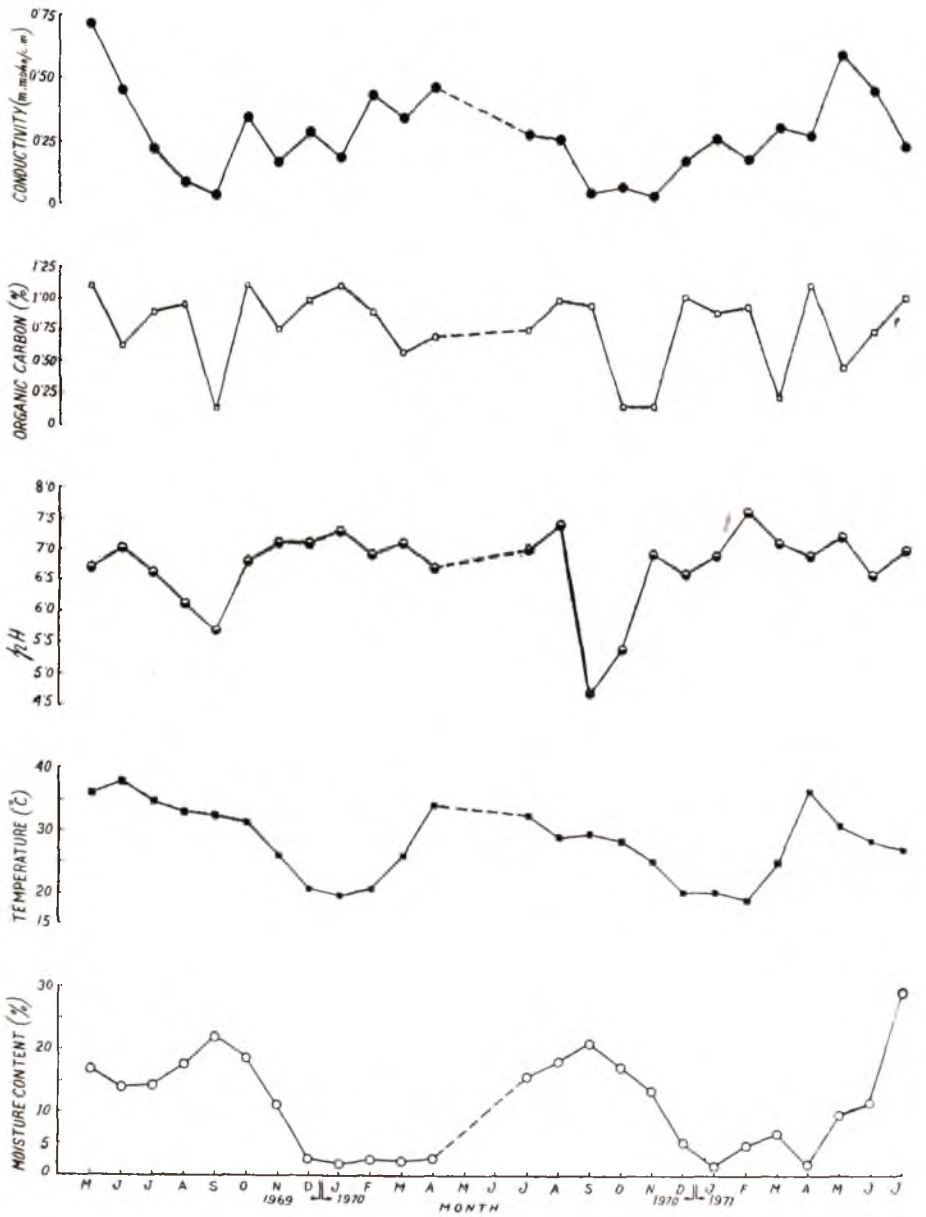

Fig. 2. Monthly variation of some edaphic factors in the site of study.

previous month, mean monthly relative humidity and air temperature at the time of sampling showed a significant positive correlation with the total microarthropod population. Collembolan population was found to have significant positive correlation with the mean monthly RH, air temperature and with the moisture content of the soil, whereas only mean monthly RH and moisture content of the soil had a significant positive

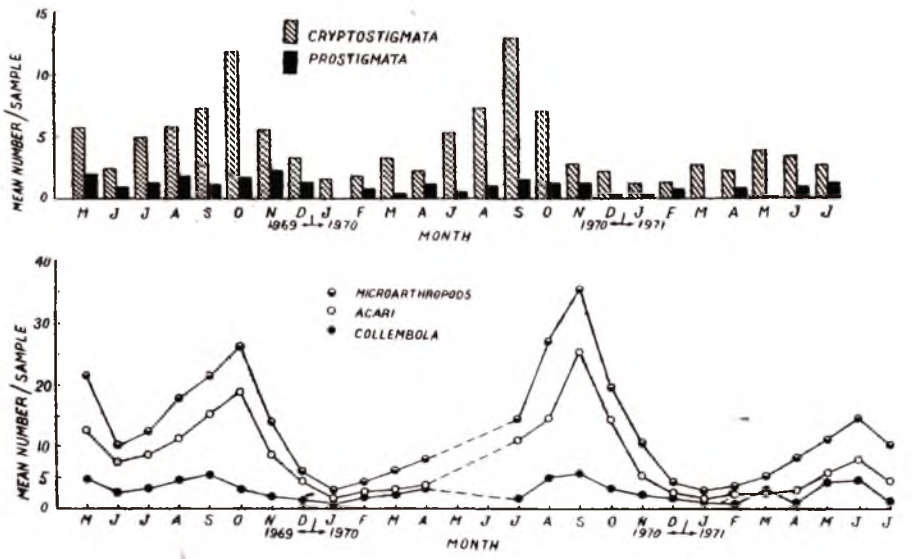

Fig. 3. Monthly variations in the density of total microarthropods and the important groups during 1969 – 1971.

correlation with the Cryptostigmata. Contrary to these, pH of the soil showed significant negative correlation with Cryptostigmata, Collembola and the microarthropods in toto.

As in the present investigation BELFIELD (1967) also found that rainfall of the previous month has significant correlation with the population of the next month. It seems, atmospheric humidity operates on soil

TABLE 1. Correlation coefficient (r) between density and individual factors.

Factor	Microarthropods	Cryptostigmata	Collembola
Rainfall of the previous month	+ 0.487 *	+ 0.368	+ 0.373
Mean monthly relative humidity	+ 0.555 **	+ 0.488 *	+ 0.41
Air temperature at the time of sampling	+ 0.522 **	+ 0.362	+ 0.552 **
Soil temperature at 5 cm depth	+ 0.441 *	+ 0.275	+ 0.374
Moisture content of soil	+ 0.756 ***	+ 0.681 ***	+ 0.553 **
Organic carbon	— 0.12	+ 0.039	— 0.219
Conductivity	— 0.155	— 0.231	+ 0.086
pH	— 0.622 ***	— 0.631 ***	— 0.59 **

*** Significant at 0.1% level of probability.
** Significant at 1% level of probability.
* Significant at 5% level of probability.

microarthropod population by influencing the relative humidity of the soil. Although KEVAN (1965) states that the air temperature is probably of less importance to soil animals than it is to surface dwelling species yet findings of the present investigation lead to a different supposition at least for total microarthropods and Collembola. It seems Cryptostigmata are less susceptible to temperature fluctuations perhaps because of the hard cuticular covering as has been suggested by MOURSI & HUSSAIN (1970), who also failed to note a correlation between the fluctuation of these mites and the air temperature. On the other hand, contrary to the present observation, DURRANT & RICHARDS (1966) believe that soil temperature bear no correlation with the soil microarthropod population.

Importance of the moisture content of the soil in determining soil microarthropod population in Indian sub-continent, was first recognised by TREHAN (1945). MUKHARJI & SINGH (1970) at Varanasi found that the microarthropod population increased when both the moisture content and temperature were high. CHOUDHURI & ROY (1972) working in West Bengal found a significant positive correlation between collembolan population and moisture content in some districts, while in some others a negative correlation was noted. The negative correlation between pH and the soil microarthropods might be due to the increased availability of fungi at lower pH on which many soil microarthropods feed. Unlike the factors discussed above organic carbon and conductivity seem to have very little to do with the fluctuation of the soil microarthropods at least at Santiniketan. Similar observation with regard to organic carbon have been made by MOURSI & HUSSAIN (1970) in Iraq, MUKHARJI & SINGH (1970) at Varansai and CHOUDHURI & ROY (1971a) at Burdwan.

In conclusion it may be said that it is perhaps the cumulative effect of various climatic and edaphic factors rather than the individual influence which is responsible for change in the population size from time to time. Rainfall together with high relative humidity during rainy season lead to an increase in the moisture content of the soil which is followed by the proliferated growth of the ground vegetation and soil microflora. High temperature during this time facilitates litter decomposition often resulting into an increase in the soil acidity, which is favourable for many soil microarthropods. Finally, comparison of pattern of population fluctuation of soil microarthropods of this area with that of other localities in India further strengthens the conviction that local environmental factors have important influence on the magnitude frequency and timing of population peaks.

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POPULATION GENETICS OF *DROSOPHILA NASUTA NASUTA*, *DROSOPHILA NASUTA ALBOMICANA* AND THEIR HYBRIDS. IV. HYBRIDIZATION AND ADAPTEDNESS

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Two related measures of adaptedness, namely, productivity and population size have been estimated in the genetic systems of *Drosophila nasuta nasuta*, *D. n. albomicana* and their F_1 hybrids. The gene pool of F_1 hybrids showed superior adaptedness than its parents. The implications of these findings are discussed.

(*Key words:* **population genetics, *Drosophila nasuta nasuta*, *Drosophila nasuta albomicana*, hybrids, adaptedness**)

INTRODUCTION

Drosophila nasuta nasuta (2n = 8) and *D. n. albomicana* (2n = 6) constitute a pair of chromosomal races in the *nasuta* subgroup of the *immigrans* group of *Drosophila* (NIRMALA & KRISHNAMURTHY, 1972; RANGANATH *et al.*, 1974). Further, RAJASEKARASETTY *et al.* (1978, 1979a,b) have reported the extent of karyotypic mosaicism and co-association of parental chromosomes in the hybrid populations as well as heterosis and co-adaptation in the above mentioned races. The present paper deals with the adaptedness of the races—*D. n. nasuta* and *D. n. albomicana* and their F_1 hybrids during inter- and intraspecific competitions.

MATERIAL AND METHODS

A chromosomally monomorphic strain of *D. nasuta nasuta* (Coorg, Karnataka, India) and an Okinawan strain of *D. nasuta albomicana* (University of Texas Collection No. 3045.11) were employed for the experiment. F_1 hybrids were obtained by making reciprocal crosses of these races. A *yw/* strain of *D. melanogaster* was used as a common competitor against these experimental populations to assess their interspecific comepetitive abilities.

Two related measures of adaptedness, namely, productivity and population size were estimated in the above mentioned populations during intra- (pure cultures) and inter- (mixed cultures) specific competitions. These populations were maintained following the serial transfer procedure of AYALA (1965) at 22°C. In pure cultures, each population was started with 50 individuals (25 males and 25 females) and they were maintained for 12 weeks. In mixed cultures, i.e., for inter-specific competition, 25 individuals of *D. nasuta nasuta*, *D. nasuta albomicana* and F_1 hybrids were separately placed with 25 individuals of *yw/* strain of *D. melanogaster* and these populations were maintained till the elimination of any of the competing species. Four replicates were set up for each set of experiments.

RESULTS

The averages for productivity of *D. n. nasuta*, *D. n. albomicana*, F_1 hybrids and of *yw/* strain of *D. melanogaster* are 52.88, 23.32, 39.70 and 164.40 respectively and similarly for population size the averages are 70.54, 50.28, 55.91 and 204.55 respectively (Table 1). The patterns of interspecific competition between *D. melanogaster* and three experimental populations are presented in Figs. 1 to 3. Here, both the populations of *D. n. nasuta* and F_1 hybrids

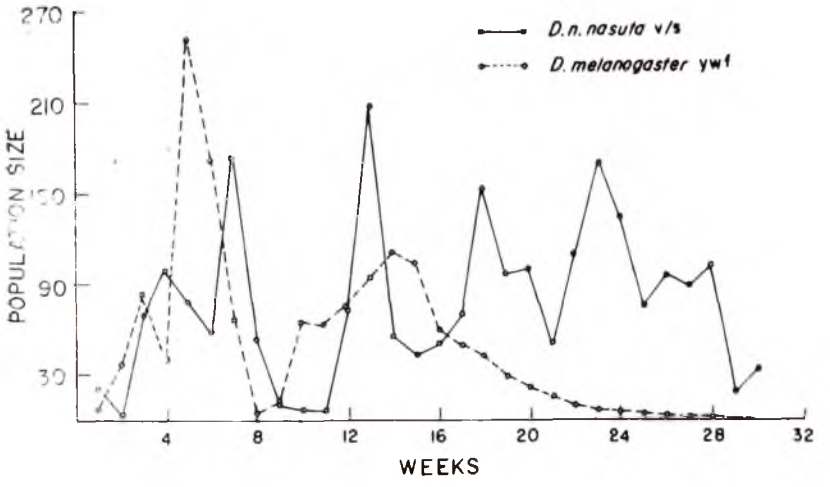

Fig. 1

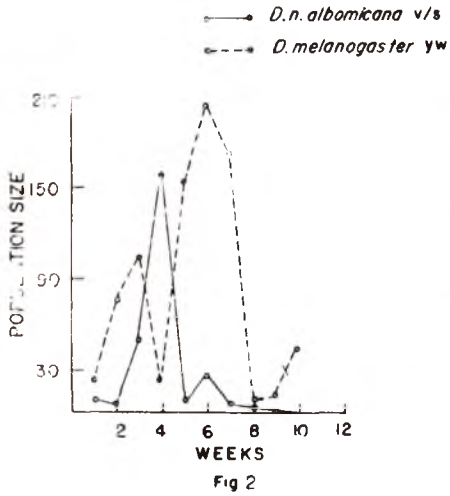

Fig 2

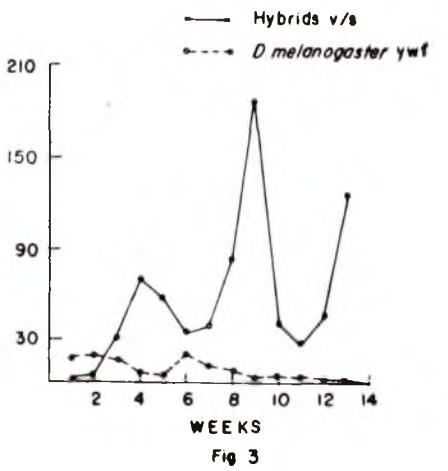

Fig 3

Figs. 1 to 3. Dynamics of interspecific competition between: *D. nasuta nasuta* V/s *ywf* strain *D. melanogaster* (Fig. 1); *D. nasuta albomicana* V/s *ywf* strain *D. melanogaster* (Fig. 2); F_1 hybrids V/s *ywf* strain *D. melanogaster* (Fig. 3).

TABLE 1. Means for productivity and population size in pure cultures of *D. n. nasuta*, *D. n. albomicana* and of their F_1 hybrids and also of *ywf* strains of *D. melanogaster*.

No.	Population	Productivity	Population size
1.	*D. n. nasuta*	34.72	49.83
2.	,,	27.18	49.50
3.	,,	86.90	105.83
4.	,,	62.33	77.00
	Mean ± SE	52.88 ± 13.65	70.54 ± 13.41
5.	*D. n. albomicana*	21.18	54.00
6.	,,	27.63	56.91
7.	,,	24.27	49.41
8.	,,	20.18	40.83
	Mean ± SE	23.32 ± 1.6	50.28 ± 3.50
9.	Started from F_1 hybrids	43.45	52.91
10.	,,	52.63	76.75
11.	,,	43.63	63.50
12.	,,	19.09	30.50
	Mean ± SE	39.70 ± 7.19	55.91 ± 9.77
13.	*D. melanogaster* (*ywf*)	171.81	207.50
14.	,,	161.72	200.83
15.	,,	155.45	192.75
16.	,,	168.63	217.14
	Mean ± SE	164.40 ± 3.65	204.55 ± 5.16

succeeded in eliminating the populations of *D. melanogaster*, and they have achieved this success in 9 to 29 weeks and 6 to 12 weeks respectively. On the other hand, the interspecific competition between *D. n. albomicana* and *D. melanogaster* revealed the elimination of the former within a span of 7 to 9 weeks. Table 2 presents the data on productivity and population size of *D. n. nasuta*, *D. n. albomicana* and their F_1 hybrids during their interspecific competition with *D. melanogaster*. In the mixed cultures, it was found that there was a significant reduction in the reproductive potential of *D. melanogaster* as compared to its performance in pure cultures (Table 3). The extent of this decline reflects the interspecific competitive fitnesses of its competitors. In this regard, the relative positions of its competitors are F_1 hybrids $<$ *D. n. nasuta* $<$ *D. n. albomicana*.

DISCUSSION

Gene pools of different races of a species are in a constant flux resulting in diversification which reflects the environmental

TABLE 2. Means for productivity and population size of *D. n. nasuta*, *D. n. albomicana* and of their F_1 hybrids during their interspecific competition with *ywf* strain of *D. melanogaster*.

No.	Population	Weeks	Productivity	Population size
17.	*D. n. nasuta*	9	65.12	70.55
18.	,,	19	65.16	83.31
19.	,,	29	54.96	77.62
20.	,,	12	56.09	66.33
	Mean ± SE		60.33 ± 2.78	74.45 ± 3.75
21.	*D. n. albomicana*	7	21.71	23.66
22.	,,	9	30.12	30.44
23.	,,	8	26.14	27.12
24.	,,	7	40.71	40.83
	Mean ± SE		29.67 ± 4.06	30.33 ± 3.70
25.	Started from F_1 hybrids	12	32.36	50.91
26.	,,	11	27.70	56.27
27.	,,	11	24.40	45.90
28.	,,	6	20.40	31.16
	Mean ± SE		26.21 ± 2.53	46.06 ± 5.39

changes spatio-temporally. If the races are allopatric, they attain different degrees of distinctness and even this, changes in time. Hybridization test is one of the potential tools to assess the extent of genetic differentiation between populations. By way of this, one can ascertain whether the population in question has attained the status of a species or not. If the test reveals that they are still open genetic systems, the extent of genetic co-adaptation in them can be analysed by comparing the performance of parent and hybrid gene pools for some fitness parameters.

The authors have estimated the adaptedness of *D. n. nasuta, D. n. albomicana* and their F_1 hybrids. A possible measure of adaptedness of a population to its environment is given by the ability of a population to transform the available resources into living matter. The adaptedness of a population to certain environments is a measure of its ability to survive and reproduce in these situations (DOBZHANSKY, 1968). Hence, the productivity and population size have been used as parameters to compare the performance of different gene pools (AYALA, 1965). Productivity is the extent of its reproductive potential, measured in terms of new born flies every week. So it is a sum total of various components of the life cycle, such as fecundity, hatchability, rate of development etc. Population size is measured in terms of the average population size it maintains during the experimental period.

TABLE 3. Means for productivity and population size of *ywf* strain of *D. melanogaster* during its interspecific competition with *D. n. nasuta*, *D. n. albomicana* and their F_1 hybrids.

No.	Population against	Productivity	Population size
17.	*D. n. nasuta*	14.37	20.44
18.	,,	13.61	18.05
19.	,,	36.28	49.82
20.	,,	15.00	19.83
	Mean ± SE	19.81 ± 5.49	27.03 ± 7.61
21.	*D. n. albomicana*	76.50	83.14
22.	,,	71.75	85.55
23.	,,	79.00	88.25
24.	,,	98.16	104.71
	Mean ± SE	81.35 ± 5.80	90.41 ± 9.47
25.	Started from F_1 hybrids	3.27	8.66
26.	,,	2.20	8.09
27.	,,	4.00	9.63
28.	,,	2.20	9.00
	Mean ± SE	2.91 ± 0.43	8.84 ± 0.31

In addition to the above mentioned components it also includes the events like viability, longevity and sexual activity of the adults. The systems which maintain a larger population size may be said to be performing better from the biological point of view than the one having small population size. In the present study, in pure cultures, *D. n. nasuta* was shown to have better adaptedness than others. The sequence as to their relative adaptedness is *D n. nasuta* < F_1 hybrids < *D. n. albomicana*. Further, during interspecific competition, *D. melanogaster* was eliminated both by *D. n. nasuta* and F_1 hybrids. The time taken to eliminate *D. melanogaster* is worth discussing. The populations of *D. n. nasuta* have taken as long as 29 weeks while F_1 hybrids have achieved the same within a span of 12 weeks. Further, as can be seen in Fig. 1 before the final elimination of *D. melanogaster* there were initial uncertainty as evidenced by oscillations in the dominance of the competing species. On the other hand, the F_1 hybrids never allowed *D. melanogaster* to dominate and in fact the overall population size of this did not raise above the initial founder population size (Fig. 3). All these observations show the better interspecific competitive fitness of F_1 hybrids. This fitness can also be discussed in terms of how far it has succeeded in curtailing the reproductive potential of its competitor. Once again, *D. melanogaster* has the least population size against F_1 hybrids than against *D. n. nasuta* and *D. n. albomicana*. By taking into cognizance of these facts, the authors opine that the F_1 hybrids of

D. n. nasuta and *D. n. albomicana* has a better and improved interspecific competitive ability than their parents.

Further, during the course of twelve weeks of interspecific competition between F_1 hybrids and *D. melanogaster* one can expect at least four to five generations of the experimental populations. Therefore the F_1 hybrids must have passed through F_2, F_3, F_4 and F_5 generations before they eliminated *D. melanogaster*. Further, during all these phases, F_1 hybrids dominated the process in contrast to the populations of *D. n. nasuta*, where there were oscillations in the dominance of the competing species. Now the crux of the problem is to account for the persistance of this interspecific competitive superiority of F_1 hybrids through F_5 generations, just because, RAJASEKARASETTY *et al.* (1979b) have already reported the occurrence of F_1 heterosis followed by F_2 hybrid breakdwon in the hybrid populations of *D. n. nasuta* and *D. n. albomicana*. So the F_2 generation itself suffers from a decline in the fitness over F_1 hybrids and *D. n. nasuta*. Similarly there is the occurrence of hybrid vigour and hybrid breakdown in the interracial/interpopulation hybridization of different species of *Drosophila* (cf. DOBZHANSKY, 1970; BRNCIC, 1954; MORIWAKI *et al.*, 1956; NAGLE & METTLER, 1969; VETUKHIV, 1953, 1954, 1956, 1957). In view of these the authors believe that the better competitive fitness of F_1 hybrids through F_5 generations under study may be due to the following reasons:

(a) there exists an increased level of genetic variability in the hybrid gene pool than in their parents, on which selection can operate.

(b) the bybrid vigor present in the F_1 generation itself might have been sufficient to suppress the overall competitive fitness of its competitor, thereby even if there is hybrid breakdown in F_2, it continues to be far better than *D. melanogaster*.

Thus, the hybridization of *D. n. nasuta* and *D. n. albomicana* has produced a hybrid genetic system with a better adaptedness than its parents.

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CHANGES IN PROTEIN TURNOVER AND RELATED BIOCHEMICAL CORRELATES DURING EMBRYONIC DEVELOPMENT OF ERISILKWORM, *PHILOSAMIA RICINI*

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Higher levels of protein synthesis is indicated by two independent peaks of RNA level during early and late days of embryogenesis in eri-silkworm but protein level itself presents variable patterns along with total free amino acid concentration, probably due to proteolysis and deamination. However, DNA content per unit weight remains almost constant.

(*Key words:* **biochemical changes, eri-silkworm, embryonic stage**)

INTRODUCTION

Great progress has been made in the field of protein metabolism and that of related biochemical correlates during post-embryonic and adult development of insects, but less so during embryonic development (WIGGLESWORTH, 1965; CHEN, 1966). During embryogenesis of insect an intensive protein metabolism takes place which involves mainly the breakdown of pre-existing yolk reserves and conversion of these into tissue and organ-specific proteins. Hence, significant metabolic changes, particularly with respect to the protein turnover, are expected during egg development for the process of cell differentiation and organogenesis.

Available literature reveals very few investigations in the field and that too present varied patterns of protein metabolism during embryonic development of insects. INDIRA (1963) observed enhanced protein synthesis accompanied by depression of yolk reserve as the development of *Sphaerodema* proceeds. A decrease in total free amino acid concentration towards late stages of embryonic development of *Culex* has been reported by CHEN & BRIEGEL (1965) indicating the probability of enhanced protein level but in *Antheraea mylitta*, PANT & SHARMA (1976) noted a decrease in total protein content during same period. Thus the situation with respect to protein metabolism in insect during egg development is ambiguous which initiated us to take up the present investigation.

MATERIALS AND METHODS

The eggs of eri-silkworm were incubated at 25 ± 1°C for about 9 days after which the first instar larvae hatched out. The day of oviposition was taken as day zero. Day-wise analysis of various biochemical correlates was made till the hatching took place. Each sample of each day consisted of 50 eggs and their weight was recorded.

The various biochemical fractions like protein, total free amino acids, RNA and DNA were fractionated by conventional procedures as described by COLOWICK & KAPLAN (1965). The eggs were homogenised in 80% ethanol and the homogenate was filtered through a fine nylon mesh so as to remove the chitinous pieces of egg covering. The protein determinations were made with the help of Folin-Ciocalteau reagent using bovine serum albumin as the standard (LOWRY *et al.*, 1961). The total free amino acid concentration was quantitatively assayed by ninhydrin reaction (MOORE & STEIN, 1948) using glycine as the standard amino

acid. Yeast-RNA hydrolysate was used as the standard for the determination of RNA content with the help of orcinol reagent (MEJBAUM, 1939). The DNA determination was made according to DISCHE's method (1930) and calf thymus DNA was used as the standard. All the optical density measurements were made on "Elico spectrocol." The data were expressed as μg mg wet weight of the eggs.

RESULTS AND DISCUSSION

The results obtained have been presented in Figure 1. It is evident that throughout the development of embryo, the DNA content per unit weight remains almost constant except little fluctuations towards later stages.

The RNA content of the developing egg increases till day 2 followed by a lower but

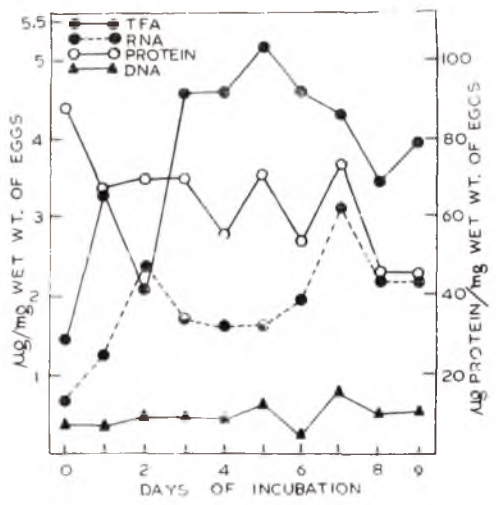

Fig. 1. Changes in certain biochemical correlates during embryonic development of eri-silkworm, *Philosamia ricini* (Mean of at least 5 samples for each point.)

constant level on days 3, 4 and 5 after which it steadily increases till day 7 when it gradually declines at the later stages. Thus two well defined peaks of enhanced RNA synthesis are observed, one in early stage, the time of blastokinesis and germ band formation and the other in late days of embryogenesis when maximum organogenesis occurs.

The amino acid pool size increases on day 1 but decreases on day 2 when there is maximum RNA level, thus initiating enhanced synthesis of embryonic proteins. On day 3 onwards till day 5 the level of free amino acid concentration steadily increases but thereafter it decreases till day 8 followed by a slight increase on the last day. A continuous higher level of total free amino acid concentration during early (except on day 2) and mid-days is in conformity with the findings of CHEN & BRIEGEL (1965) in the embryo of *Culex*. Similar observations have been reported for *Schistocerca gregaria* by COLOMBO *et al*, (1961) and in the embryo of *Sphaerodema molestum* by INDIRA (1963). The decrease in amino acid pool size towards later stages of development associated with higher level of RNA on day 7 is certainly related to higher protein biosynthesis.

Total protein content in the egg presents interesting variations during development. The protein level decreases on day 2 from its initial higher level which is probably reflected by corresponding increase in amino acid concentration but its level on day 2 and 3 remains almost constant. This level is maintained on day 5 with sufficient decrease on day 4 and 6 respectively. Thereafter a higher level than earlier one on day 7 is observed when RNA level is at maximum. Afterwards the protein level gradually decreases till hatching of the first instar larva. The gradual derease in protein level during late days of embryogenesis and also decrease in total free amino acid concentration might be related to the process of proteolysis and deamination so as to produce glucosamine needed for chitin biosynthesis. Accordingly, an increased depletion of

glycogen accompanied by enhanced phosphorylase activity at this time (PANT & SHARMA, 1976) can be well anticipated. A similar decrease in protein level during embryonic development of *Antheraea mylitta* has been noticed by the above authors but in constrast, PANT & NAUTIYAL (1974) observed increased protein level on the eve of emergence of first instar larva of *P. ricini* which is not in conformity with the present observation. A sharp fall in amino acid pool size and increase in RNA level on day 2 apparently do not result in appreciable higher protein level which might be correlated with partial utilization of amino acids in the TCA cycle for energy production during the period when there is higher energetic demand for the initiation of blastoderm formation.

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STUDIES ON THE BIONOMICS OF *TRIOXYS* (*BINODOXYS*) *INDICUS* SUBBA RAO & SHARMA (HYM., APHIDIIDAE): A PARASITOID OF APHIS CRACCIVORA KOCH. (HEM., APHIDIDAE): IV. FUNCTIONAL RESPONSE OF THE PARASITOID

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The present work elucidates functional response of *Trioxys* (*Binodoxys*) *indicus* showing linear relationship between the degree of mortailty and the density of *Aphis craccivora*. *T. indicus* showed capability of attacking 46.8±6.6 aphids female at host population of 100 aphids, but attacked fewer hosts (12.0±2.9 aphids female) at a population of 25 aphids during the same period (15 minutes). Such response of *T. indicus* points out its searching capability which increases with host population, reflecting its suitability for the biological control of pigeon pea (*Cajanus cajan* MILL.) aphid.

(*Key words: Trioxys* (*Binodoxys*) *indicus*, *Aphis craccivora*, **parasitoid, host, functional response, parasitization, mortality, k value**).

INTRODUCTION

Aphis craccivora is a major pest of the pulse yielding crop, *Cajanus cajan* (SINHA & SINGH, 1979). The study of bionomics of *Trioxys* (*Binodoxys*) *indicus* on *A. craccivora* has already established its importance as a potential bioagent (SINHA & SINGH, 1979). Functional response (SOLOMON, 1949) of the parasitoids is essential for clear understanding and proper approach to the modelling of host-parasitoid interactions (HUFFAKER *et al.*, 1971; ABLES & SHEPARD, 1974). Understanding the basic behavioural response of an individual parasitoid to changing host density, is considered to be of central importance (HOLLING, 1966); the response is basically of three types; (1) a linear response in which attack rate is directly proportional to host density, (2) the number of hosts attacked increases rapidly at first, then progresses slowly, and finally tends to stabilize, and (3) a sigmoid relation denoting an initial increase followed by a subsequent decrease in attack rate. HUFFAKER *et al.* (1971) and HASSEL & MAY (1973) considered that *type 1* represents the response implying regulatory possibility as far as the functional response alone is concerned. In this work, an attempt has been made to obtain information about functional response elicited from *T. indicus*.

MATERIAL AND METHODS

For the culture of aphids and the parasitoids and the experimental set up see SINHA & SINGH (1979). The functional response was examined by exposing 25, 50, 75 and 100 aphids separately/parasitoid for 15 minutes. Five replicates were performed. The number of aphids recovered alive, observed dead and parasitized were recorded. Parasitized aphid is that which yields parasitoid (see SINHA & SINGH, 1979). Data were analysed statistically (regression analysis).

RESULT AND DISCUSSION

The functional response of *T. indicus* could be explained by a linear relationship ($r = +0.904793, P < 0.001$) between mortality of hosts and the host density. The number of hosts killed increases whereas the percentage decreased as the host density increased (Fig. 1). *T. indicus* parasitized 78.4% of aphids at a density of 25 and only 61.2% at a density of 100 aphids. The optimum host density, for *T. indicus*, seemed to exceed 100, because the response curve did not level at 100 aphids. The observations are in conformity with those of ABLES & SHEPARD (1974) with respect to pteromalid wasps. The total number of parasitoids emerged (linearly correlated, $r = +0.945889$, $P < 0.001$) from each experiment is less than the total number of hosts killed. Host density did not significantly influence the percentage of parasitoid emerged ($r = -0.019317$, $P > 0.900$, Fig. 2). These observations suggest that *T. indicus* searches, locates and oviposits in the hosts more rapidly at higher host densities. When *A. craccivora* crushed (chitinised parts removed) on blotting paper (Whatman No. 1) and was exposed to *T. indicus*, it was observed that the parasitoid locates the spot, touches it with her antennae and bends her abdomen in the same fashion as she does during stinging of aphids for oviposition. The above observation revealed that *T. indicus* locates the host by some sort of olfactory chemosensation, which also activate the parasitoid's behaviour (JONES *et al.*, 1973). Higher incidence of parasitization observed at increased host densities might be due to the higher concentration of host-seeking stimulants present at those densities than at lower ones.

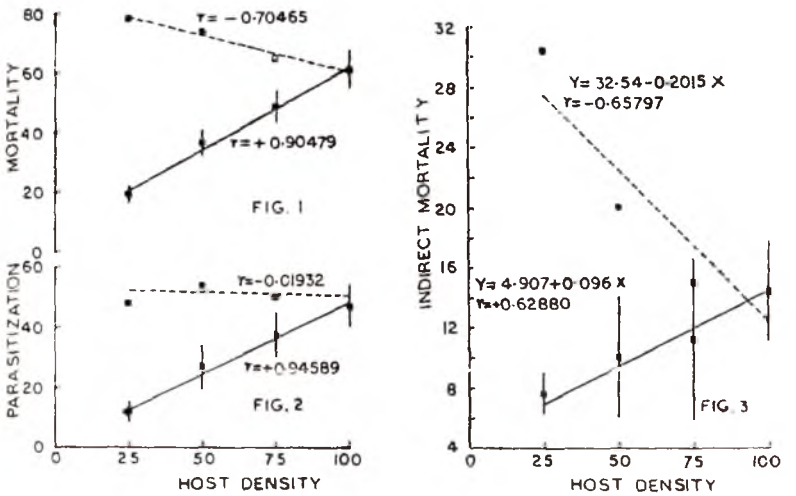

Fig. 1. Relationship of *Aphis craccivora* density on the average number (———) and percentage (– – –) mortality of *A. craccivora* caused by individual *Trioxys* (*Binodoxys*) *indicus*.

Fig. 2. Relationship of *Aphis craccivora* density on the average number (———) and percentage (– – –) parasitization of *A. craccivora* parasitized by individual *Trioxys* (*Binodoxys*) *indicus*.

Fig. 3. Relationship of indirect mortality of *Aphis craccivora* at its different densities caused by individual *Trioxys* (*Binodoxys*) *indicus*. (———) in number and (– – –) in percentage.

Regression analyses were used to determine the role of a single parasitoid responsible for "indirect" mortality at different host densities. Here the "indirect" mortality of aphids includes such sphids which were killed mainly due to mutilation, without producing parasitoids. The results indicate that the number of "indirect" mortality linearly increases with host population ($r = +0.62880$, $P<0.01$, Fig. 3). However, the percentage of "indirect" mortality of *A. craccivora* ($r = -0.65797$, $P<0.01$) yielded similar results as mentioned for earlier observation (see Fig. 1). A possible explanation of this may be that at higher host densities the concentration of the stimulants will be quantitatively more which will stimulate the activity of parasitoid causing increased number of prickings (with or without egg laying).

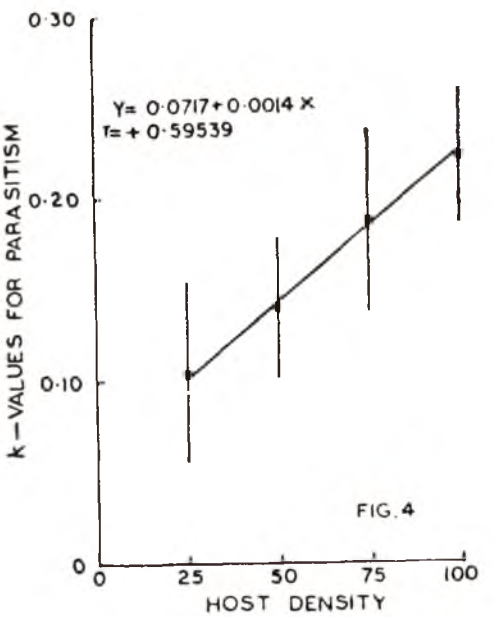

Fig. 4. Effect of host density on the rate of parasitization of *Aphis craccivora* by *Trioxys* (*Binodoxys*) *indicus*.

Data (unpublished) suggest that the number of prickings is positively correlated with the "indirect" mortality of the aphids.

Behavioural response of *T. indicus* to host density was also measured using the expression of k-values (VARLEY & GRADWELL, 1960). The slope of the regression line is significant ($r = +0.59539$, $P<0.01$) (Fig. 4). Our findings thus confirm a density-dependent relationship between *T. indicus* and *A. craccivora*, which indicate that the parasitoid has a non-random searching pattern (ROGERS, 1972) with regard to host density. This type of relationship has also been observed in some other aphidiid wasps (MESSENGER & FORCE, 1963; BOSCH *et al.*, 1966; MESSENGER, 1968).

The functional response of *T. indicus*, therefore, is similar to that of *type 1* of HOLLING (1959). However, if host density is further increased to 200 or more (hypothetical), the parasitoid might not have been able to attack proportionately as it does below 100 hosts and would have followed the functional response of *type 2*, which is the "typical" functional response (HASSELL *et al.*, 1976). Though analysis of models containing one of the three types of functional response indicated that *type 3* response provides stability (HOLLING, 1965; HUFFAKER *et al.*, 1971; HASSELL & MAY, 1973), the presence of *type 1* and/or *2* functional response as evident in the present case can by no means should be used to underscore a potential bioagent as incapable for the regulation of host population, because in the establishment of host-parasitoid interactions, it is the 'numerical response' (SOLOMON, 1949) of parasitoids which plays greater role (HUFFAKER *et al.* 1971; 1976).

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BIO-ECOLOGY OF *HELOPELTIS ANTONII* SIGN. (MIRIDAE: HEMIPTERA) INFESTING CASHEW TREES

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The bionomics and morphometrics of *Helopeltis antonii* (Miridae: Hemiptera) a major pest of cashew in Kerala has been studied under laboratory conditions. Periodical sampling of field populations revealed that in nature females always predominate, the range in the ratio of ♀ to ♂ being from 1:0.49 to 1:0.62. The pre-oviposition and oviposition periods at 25±0.5°C lasted for 4 and 6 days respectively. The life cycle from egg to adult emergence occupied 22.2 days at 28±1°C, the duration of the different stages being 1.3, 2.1, 3.5, 3.2, 3.3 and 2.8 days for the egg and nymphal instars I, II, III, IV and V respectively. The morphometrics of adults and immature stages are presented. The symptoms were more pronounced at 31±0.5°C. The occurrence of *Crematogaster wroughtoni* FOREL (Myrmecinae: Formicidae: Hymenoptera) as a predator of the I and II instar nymphs of *H. antonii* was recorded for the first time. The optimum temperature for fertilization and oviposition was 25±0.5°C while for embryonic and post-embryonic development, the temperature preferendum was around 28±0.5°C. The oviposition was suppressed at 31±0.5°C.

(*Key words: Helopeltis antonii*, **life history, ecology**)

INTRODUCTION

The tea mosquito *Helopeltis antonii* SIGN. is the most serious pest of cashew in South India, causing inflorescence blight and drying up of tender shoots and nuts. Yeild losses up to 30% had been reported due to inflorescence blight incidence (ANONYMOUS, 1966). The insect also occurs on guava, cocoa, neem etc. (RAO, 1915; PUTTARUDRIAH & APPANNA, 1955) and it can, therefore, multiply uninterruptedly throughout the year. Preliminary studies on the biology of the insect have been carried out by PILLAI & ABRAHAM (1974), PILLAI *et al.* (1976), SUDHAKAR (1976), and SATHIAMMA (1977). The studies were carried out in the Cashew Research Station, Vellanikkara, College of Horticulture, Vellanikkara 1977 – 1978 to gather additional information on the bio-ecology of the pest and results are reported in the present contribution.

MATERIALS AND METHODS

For biological studies, insects were reared out from field collected nymphs confined on apical shoots of cashew seedlings of 6–8 months growth, enclosed in perforated polybags (150 gauge). The adults thus reared out were sexed and pairs were confined on tender shoots of potted cashew seedlings and these were kept at 25 ± 1°C in the insectary for oviposition. The distribution of eggs and fecundity were registered by dissecting out the shoots on termination of the ovipositional period. The embryonic and post-embryonic developmental stages were studied at 28±1°C in BOD incubator. The first instar nymphs hatching out were transferred to fresh tender shoots for further development. The influence of varying levels of constant temperatures was studied by confining freshly emerged adults in potted plants kept in BOD incubators at 75±1% RH.

In order to study the feeding behaviour, 10 individuals in each instar were separately confined on tender twigs of potted seedlings enclosed in perforated polybags and incubated at 28 ± 1°C. Excised floral branches and branches with tender nuts were separately inserted in glass bottles con-

taining water and held in position by cotton pads. The stages of insects were confined to these using polybag cages for studying the feeding behaviour.

The predatory populations were directly counted from randomly selected shoots by vigorously shaking the shoots to dislodge the host stages and the prey to square cloth trap held in position by marginal and diagonal wire framework. The suspected predators were directly counted in the field and thereafter brought to the laboratory for studies on feeding potential.

RESULTS AND DISCUSSION

Adult stage:

On emergence the adults are light brownish and develop the characteristic colouration in about 30 minutes and become blackish brown; dorsum of thorax reddish in both sexes; tergum of abdomen dull whitish; tarsi 3 segmented; the adult female (Fig. 1) about 8 mm long, 0.76 mm across thorax. The adult male (Fig 2) is relatively smaller, the measurements being 6×0.74 mm ($n = 25$).

The scutellar horn (Fig. 3) is reddish brown and it is erect, tapering and the apex is swollen and funnel shaped. Antenna 4 segmented, basal segment stouter creamy white, the terminal segment with short stout trichoid bristles and the subterminal segment with sparsely distributed and relatively finer spatulate bristles; dorsum of abdominal segments 1 to 8 dull creamy white; the forewings overlap the entire body, the distal end of clavus shows a triangular brownish black discolouration while the cuneus has suffussion throughout.

Legs with deep brown tibia, femur with scattered and irregular deep brownish patches. Tarsus in males and females of equal length (.65 mm) and blackish. Copulation takes place one day after emergence and the pre-oviposition period lasts for four days. Prior to oviposition, the females are very active and they fly around the preferred oviposition sites.

In the adult field populations, the females always predominate and the ratio of females to males during October 1977 to 1978 ranged from 1:0.49 to 1:0.62. The mean longevity of females is 6.5 days ($n = 30$; range 5–7 days) while the male life span lasts for 5.2 days only ($n = 30$; range 4–6 days). The mean fecundity of females is 31.15 days ($n = 30$; range 28–35) at $25 \pm 10°C$ under laboratory conditions.

Egg stage:

Eggs (Fig. 4) are inserted into the epidermal tissues of the tender shoots and inflorescence axes and in nuts these being the preferred sites for oviposition. Rarely the eggs are embedded in the tender portions of the leaf stalks and ventral aspects of the midribs of leaves. The eggs are sub oval, bent near the neck, each having two unequal silvery filaments arising laterally on either side of the anterior end. The larger filament protrudes outwards through the oviposition site, while the shorter one is mostly embedded in the plant tissues. The larger and shorter filaments 0.5 mm and 0.4 mm long respectively. Usually the eggs are laid in 2 rows of 3 each; each egg is 1 mm long and 0.25 mm broad at the broadest middle region; chorion smooth offwhite and leathery; the incubation period lasts for 7.3 days ($n = 100$; range 5–9).

First instar nymph

This (Fig. 5) crawls out of the egg through the anterior end. The newly hatched nymph is 1.4 mm long and 0.47 mm broad across the thorax. Abdomen dull light orange, head, antennae, legs dull light orange with suffusion of brown; abdomen with 2 parallel rows of bristles running along the mid-dorsal line and with one deep brown wart each on the lateral margins of the abdominal segments; antenna 4 segmented, orange with terminal segment club shaped; legs long, tarsus 2 segmented, the basal piece

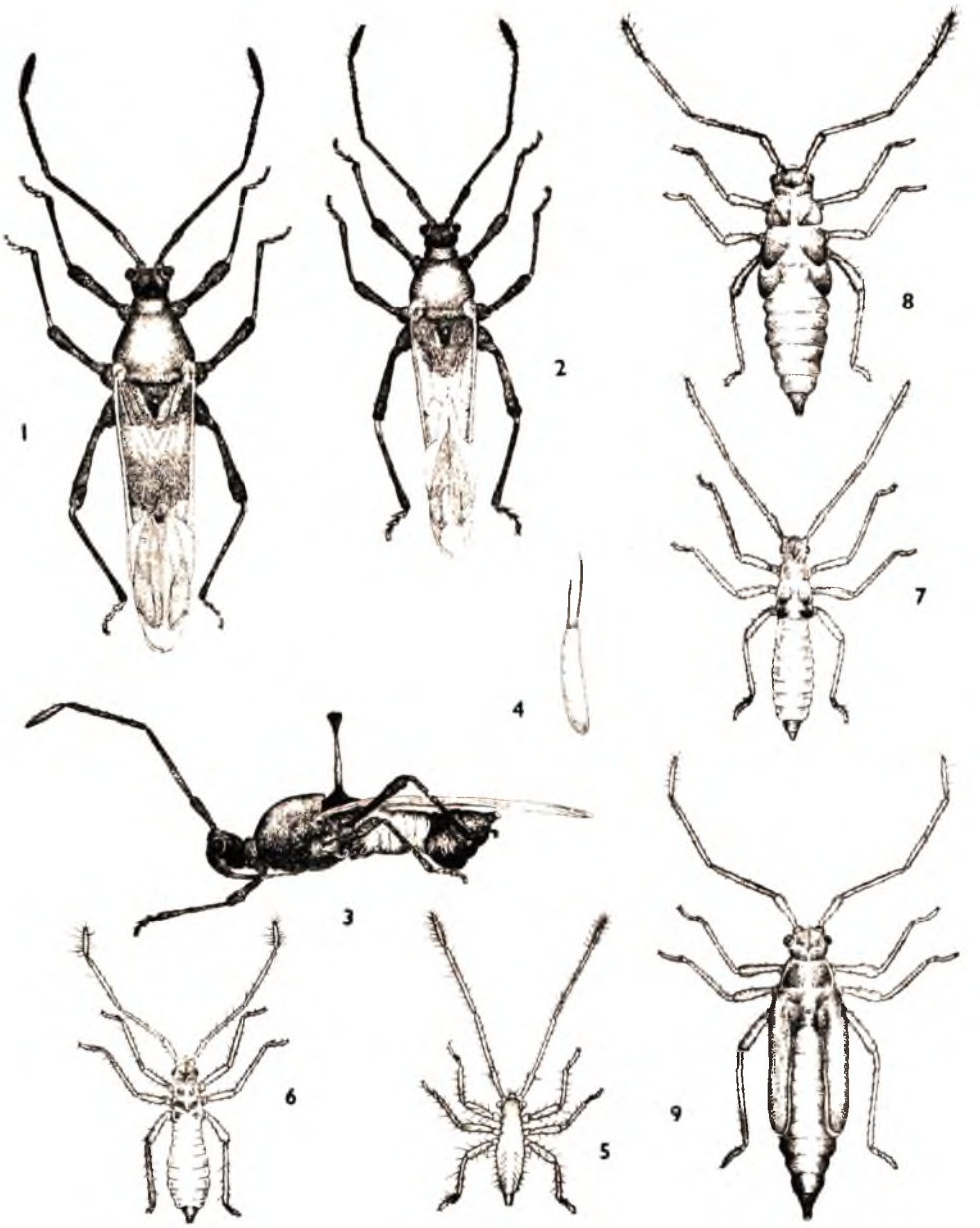

Fig. 1. Female *H. antonii*; Fig. 2. Male *H. antonii*; Fig. 3. Lateral view of *H. antonii* showing the scutellar horn; Fig. 4. Egg; Fig. 5. First instar nymph; Fig. 6. Second instar nymph; Fig. 7. Third instar nymph; Fig. 8. Fourth instar nymph; Fig. 9. Fifth instar nymph.

minute and truncated, lateral claws sickle shaped with short spine like empodium; legs, antennae and thoracic segments bear spatulate hairs basal segment and fourth segment of the antenna clothed with trichoid hairs; wing rudiments and scutellar horn absent. The first instar nymphs are active and move about briskly on tender shoots and inflorescence. Moulting takes place in 2–3 days (n = 30; mean 2.1).

Second instar nymph:

Head, antennae, legs, thorax and abdomen deep orange in colour; 1.7 mm long and 0.6 broad across the thorax; knobbed dull white scutellar horn present; wing buds clear. Tarsus 2 segmented, lateral claws sickle shaped with spine like empodium. Antenna 4 segmentd sexes not distinct. Second instar (Fig. 6) lasts for 3.5 days (n = 30; range 2–4).

Third instar nymph:

Light brownish measuring 2.37 × 0.65 mm; abdominal terga 1–8 develop uniform dull creamy wite colouration; antenna 4 segmented; leg segments uniformly light brown; tarsus 2 segmented; wing rudiments prominent. Third instar nymph (Fig. 7) moults in 3.2 days (n = 30; range 2–4 days).

Fourth instar nymph

Length 2.68 mm, breadth across thorax 0.6 mm; antenna 4 segmented, long, deep brown; dorsum of abdominal segments 1–8 with posteriorly directed dull creamy white crescentic markings. Abdominal terga 1–8 uniformly coloured dull creamy white; wing pads prominent not overlapping. Tarsi 2 segmented, long; sexes cannot be indentified in the fourth instar (Fig. 8) which lasts for 3.3 days (n = 30; range 3–4 days).

Fifth instar nymph

Sexes distinguishable on the basis of external genitalia and size variations; females and males measure 3 mm long and 0.7 mm broad across thorax, and 2.7 mm × 0.7 mm respectively; antenna 4 segmented in both sexes. Thorax reddish purple; both sexes deep brownish, the antennae and the appendages being more deeply coloured than the abdomen. The crescentic whitish dorsal patch and the ventral abdominal colouration attain a deeper hue as the development progresses in the fifth instar (Fig. 9). Wing pads overlap scutellar horn, welll developed tarsi two segmented. The duration of the fifth instar lasts for 2.8 days (n = 30; range 2–4). The morphometrics of *H. antonii* are presented in Table 1.

Total life cycle from egg to adult emergence occupies 22.2 days at 28 ± 1°C. The results of the present studies are in general agreement with previous reports by SUDHAKAR (1976), PILLAI & ABRAHAM (1974). The shorter developmental period under these conditions is explicable on the basis of widely fluctuating temperature and humidity conditions. In the present studies the females were found to survive for a longer period (6.5 days) than males (5.2) at 28 ± 1°C, and this is at variance with the results reported by PILLAI & ABRAHAM (1974) and PILLAI *et al.* (1976) that the males live for relatively longer period of 9.5 days than the females (7 days).

Feeding habits and nature of damage:

The feeding habits of adults and nymphs were similar. The fifth instar nymphs inflicted relatively greater damage. These nymphs congregate on tender shoots, leaf petioles and around secondary veins of leaves close to the midrib and feed. When large populations were confined on small twigs

TABLE: 1. Morphometrics (mean values in mm) of adults and immature stages of *H. antonii*.

Stage	Number	Length	Breadth	Length of antenna					Length of rostrum				
				Scape	pedical	post pedicel	Last segment	Total	First segment	Second segment	Third segment	Total	Length of tarsus
Adult female	25	8	0.76	0.42	0.73	0.71	0.35	2.21	0.31	0.72	0.50	1.53	0.65
Adult male	25	6	0.74	0.42	0.72	0.70	0.35	2.19	0.30	0.70	0.45	1.45	0.65
Egg	100	1	0.25	..	..	..	..	..	..	..	..	..	..
I instar	30	1.422	0.474	0.20	0.40	0.30	0.20	1.10	0.12	0.27	0.18	0.57	0.15
II instar	30	1.738	0.632	0.22	0.41	0.32	0.21	1.16	0.15	0.30	0.21	0.66	0.19
III instar	30	2.37	0.65	0.25	0.44	0.33	0.22	1.24	0.17	0.31	0.25	0.73	0.25
IV instar	30	2.686	0.65	0.25	0.45	0.34	0.23	1.27	0.19	0.32	0.27	0.78	0.47
V instar female	30	3	0.72	0.42	0.71	0.69	0.31	2.13	0.22	0.35	0.31	0.88	0.55
V instar male	30	2.70	0.72	0.40	0.70	0.69	0.31	2.10	0.21	0.33	0.29	0.83	0.55

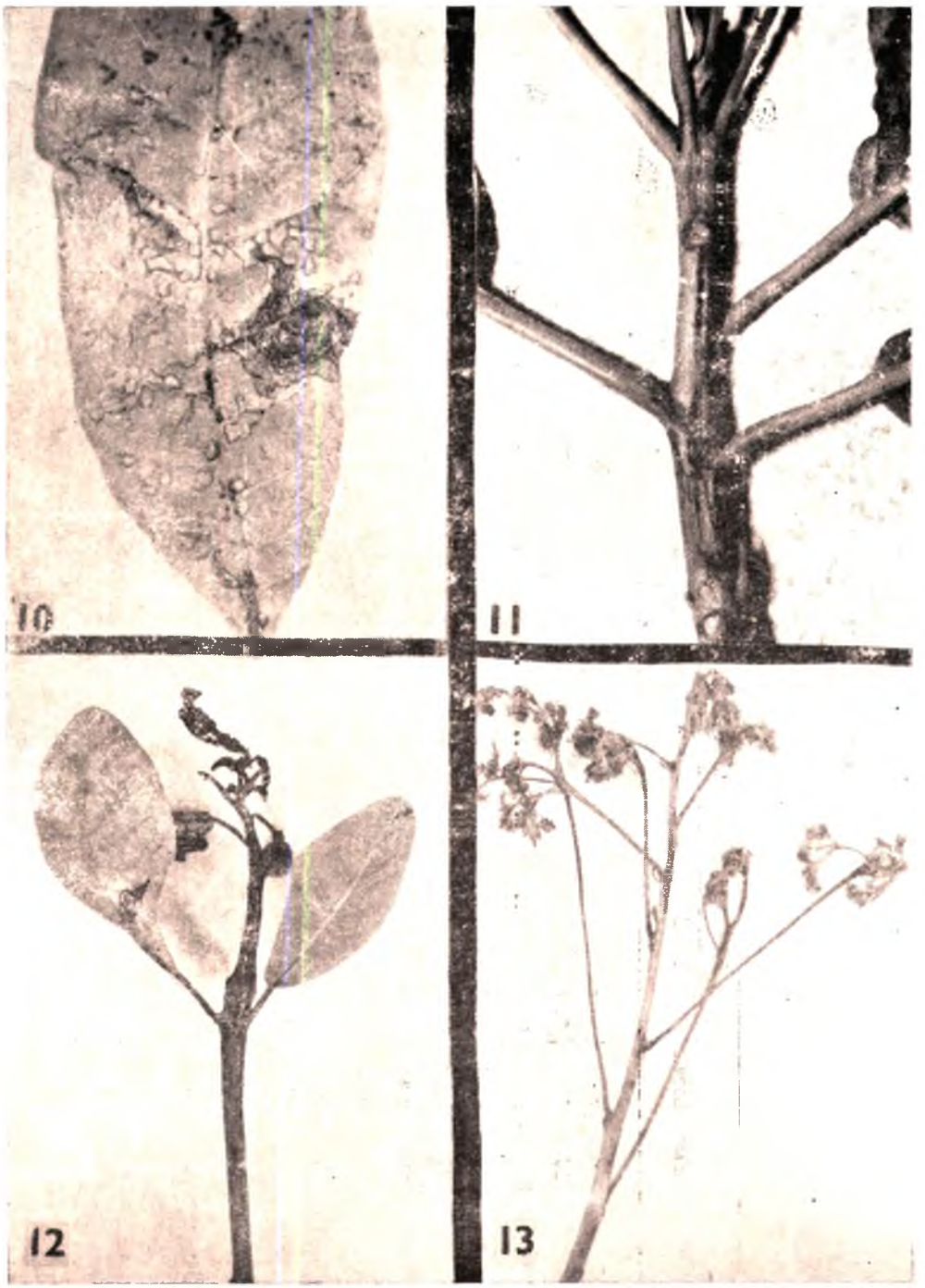

Fig. 10. Foliage symptoms incited by *H. antonii*; Fig. 11. Cashew shoot showing necrotic streaks and brownish patches caused by *H. antonii*; Fig. 12. Die-back of cashew shoots due to severe attack of *H. antonii*; Fig. 13. Cashew inflorescence showing feeding punctures caused by *H. antonii* around the nodes in main axis.

feeding takes place all over the laminae of tender foliage causing dense necrotic lesions all over. On the leaves, nerly truncate water soaked lesions develop around the feeding puncture and the tissues eventually dry up leaving brownish black non-coalescing necrotic patches. Similar foliage symptoms were observed under field conditions in August–September just preceding the flush emergence (Fig. 10). On the shoots (Fig. 11) elongate streaks and brownish patches develop on either sides of the feeding puncture and these regions dry up eventually. A resinous substance exudes from the feeding puncture on the shoots and the exudate dries up and hardens on exposure to air. The gummy exudation is more around punctures on relatively harder tissues on the shoots. The shoot apices eventually dry up (Fig. 12). The adults and fifth instar nymphs under confinement in cages containing 2 months old cashew seedlings caused shoot damge of a similar nature, but exudation of gummy substance from necrotic lesions was not observed under such conditions.

On the inflorescence, feeding is usually restricted to the main axis around the nodes (Fig. 13). Necrotic lesions due to insect feeding are more concentrated around apical nodes. The tissues and the feeding puncture dry up.

The insects also feed on the secondary floral branches causing irregular elongate shiny, rusty brown lesions, but these lesions do not show gummy exudates. The immature nuts and apples develop the characteristic scabby spots. The observations on the feeding damage are in general conformity with earlier observatons (PILLAI & ABRAHAM, 1974, 1975; SATHIAMMA, 1977).

For the first time, *Crematogaster wroughtonii* FOREL (Myrmecinae; Formicidae; Hymenoptera) was recorded as a predator

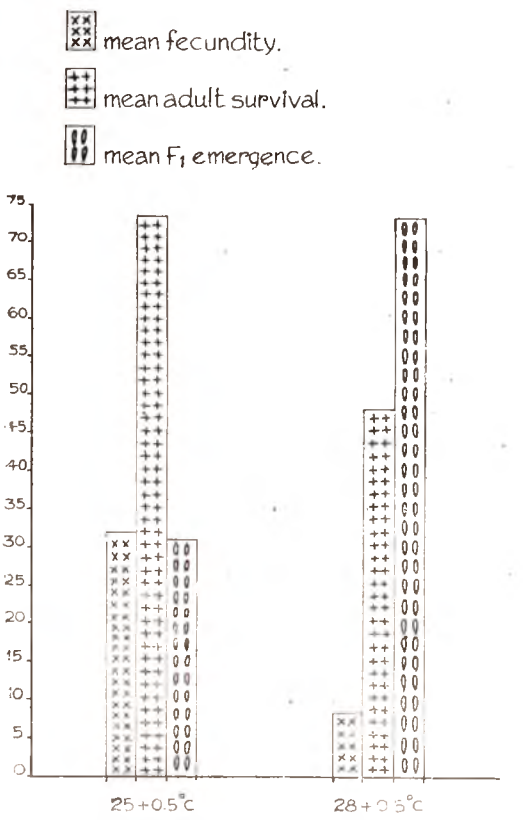

Fig. 14. Fecundity, adult survivial and F_1 emergence of *H. antonii* under different levels of constant temperatures.

of first and secnd stage nymphs of *H. antonii* under field conditions. The ants actively moved about the shoots and floral branches and devoured the nymphs. The ant populations attain a peak during August–September. Each ant is capable of devouring about ten nymphs per day. The predatory habit of *Crematogaster* on the coffee leaf miner *Leucoptera coffeela* (GUER MEN) in Peru (ENRIQUEZ *et al.* 1976) and on the coffee berry borer *Hypotenemus hampei* (FERR) in Brazil (DA FONSECA & ARAUJO, 1939) had been reported earlier.

Ecological studies:

Ten pairs of adult insects each were confined on tender shoots of potted cashew

seedlings inside perforated polybags and incubated at 25 ± 0.5°C, 28 ± 0.5°C and 31 ± 0.5°C in BOD incubators to study the influence of these levels of constant temperatures on the survival of *H. antonii*. The RH inside the incubators was around 75%.

Data depicted in Fig. 14 indicate that among the constant temperature ranges tried 25 ± 0.5°C level is the most suitable for fertilization and oviposition, while the level 28 ± 0.5°C is ideal for embryonic development and progeny production. At 31 ± 0.5°C none of the adults survived at 24 hours after confinement and the females did not lay any eggs. However, the tender shoots and foliage which were confined at this temperature revealed feeding injuries and the necrotic lesions around feeding punctures. The manifestation of tissue damage under high temperature conditions was relatively rapid.

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BIO-EFFICACY OF *BACILLUS THURINGIENSIS* BERLINER AGAINST *HELIOTHIS ARMIGERA* HUBNER ON GRAM (*CICER ARIETINUM* LINN.)

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Different doses of Dipel, HD–1 strain of *Bacillus thuringiensis* BERLINER were evaluated against 3rd and 5th instar larvae of *Heliothis armigera* HUBNER on gram (*Cicer arietinum* LINN.). An application of 12.00 × 10^9 IU/ha (750 g/ha) against 3rd instar and 16.00 × 10^9 IU / ha (1000 g/ha) against 5th instar was found to be effective within 96 hours after treatment giving 100% control of the test insect.

(*Key words:* **bio-efficacy,** *Bacillus thuringiensis*, *Heliothis armigera*)

INTRODUCTION

Heliothis armigera HUBNER, commonly known as gram pod borer occupies a major status in the pest complex of gram (*Cicer arietinum* LINN.). Though the pod borer infestation starts from the very early stage of the crop, the peak period of the pest activity synchronizes with the pod formation and thus results in heavy retardation in yields. Since a significant part of the crop is marketed with green pods for consumption, the application of toxic insecticides is hazardous and should be limited. The present study was conducted on Dipel, a commercial wettable formulaton based on HD–1 strain of *Bacillus thuringiensis* BERLINER, against *H. armigera.*

MATERIALS AND METHODS

Dipel, a commercial wettable formulation based on HD–1 strain of *B. thuringiensis* having the potency of 16000 IU/mg supplied by M/S Ag–Chem International, New Delhi was used in the present study against two larval instars (3rd and 5th) of gram pod borer. From the field collected larvae, healthy 3rd and 5th instar larvae were sorted out on the basis of head width for experimentation. The test insects were kept under stravation for 8 hours to ensure consumption of treated food during exposure hours. The experiment was laid out in complete randomized block design with 6 treatments including control replicated four times.

The doses tested were 1000, 750, 500, 250 and 125g per hectare of Dipel diluted in 1000 l of water. The doses were respectively equivalent to 16.00, 12.00 8.00, 4.00 and 2.00 billions of International Unit (IU). The gram plots measuring 2m × 5m were sprayed with each concentration to the point of slight run off with required amount of Dipel in water to which Sandovit at the rate of 0.5 ml/l of spray fluid was added as sticker. The treated succulent foliage of each concentration was brought to the laboratory after 2 hrs of spray and placed in the petri-dishes. Ten larvae were taken in each replication and 1 larva was released in each petri-dish (5 cm) to avoid cannibalism. The larvae were allowed to feed freely on treated leaves for 48 hours, after which fresh food was supplied. Separate observations were recorded on mortality for 3rd and 5th instar larvae at 24, 48, 72 and 96 hrs after treatment.

RESULTS AND DISCUSSION

The observations recroded on the effectiveness of different doses of Dipel against *H. armigera* on gram are presented in Table 1.

No significant difference was recorded between the doses of 16.00 × 10^9 and 12.00 × 10^9 IU/ha upto 72 hours after treatment.

TABLE 1. Efficacy of *Bacillus thuringiensis* BERLINER against *Heliothis armigera* HUBNER on gram.

S. No.	Dose/ha (g)	IU/ha	Average percent mortality indicated hours after treatment							
			3rd instar				5th instar			
			24 hrs	48 hrs	72 hrs	96 hrs	24 hrs	48 hrs	72 hrs	96 hrs
1.	1000	16.00×10^9	30.00 (33.05)	60.00 (50.68)	85.00 (67.50)	100.00 (90.00)	22.50 (28.28)	50.00 (44.91)	70.00 (56.64)	100.00 (90.00)
2.	750	12.00×10^9	25.00 (29.88)	55.00 (47.88)	75.00 (60.11)	100.00 (90.00)	17.50 (24.53)	45.00 (42.11)	60.00 (50.68)	90.00 (71.56)
3.	500	8.00×10^9	17.50 (24.53)	40.00 (39.16)	60.00 (50.83)	80.00 (63.81)	7.50 (13.83)	35.00 (36.22)	50.00 (45.00)	70.00 (56.95)
4.	250	4.00×10^9	12.50 (20.47)	30.00 (33.05)	45.00 (42.11)	65.00 (53.78)	0.00 (0.00)	20.00 (26.19)	37.50 (37.66)	55.00 (47.88)
5.	125	2.00×10^9	0.00 (0.00)	15.00 (22.50)	30.00 (33.05)	45.00 (42.00)	0.00 (0.00)	10.00 (18.44)	20.00 (26.19)	35.00 (36.22)
	Control		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	CD at 5%		5.82	7.63	7.52	5.22	7.14	7.63	7.99	4.75

Figures in parentheses are the angular transformed values.

in both the instars, 3rd and 5th. The 3rd instar larvae proved to be more susceptible to the different concentrations of Dipel than 5th instar. All the treatments were found to be significantly superior over control at all the intervals of observations. None of the treatments gave 50% kill at 24 hours post-treatment; however, the mortality counts increased with the lapse of the time in both the instars.

Maximum mortality (100%) was recorded at 96 hours post-treatment for 3rd instar larvae with 12.00×10^9 IU/ha and 5th instar larvae treated with 16.00×10^9 IU/ha; thus these concentrations can be recommended as effective control measures against *H. armigera*.

The present findings are in agreement with those reported by NARAYANAN *et al.* (1970) against *Plutilla maculipennis* CURTIS, YENDOL *et al.* (1973) against *Porthetria disper* L., TAYLOR (1974) against *Sylepta derogata* F. and MATHUR *et al.* (1977) against *Amsacta moorei* BUTLER.

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STUDIES ON THE GRANULOSIS OF *PERICALLIA RICINI* FABRICIUS (ARCTIIDAE: LEPIDOPTERA)

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Larvae of *Pericallia ricini* F. (Arctiidae, Lepidoptera) infected with the granulosis virus exhibited all the typical symptoms. Incubation period of the virus increased as the larvae advanced in age, the LT_{50} values for the 1st to 5th instars ranging from 3.370 to 8.523 days; 6th instar larva was highly resistant to the infection. Treatment of eggs of *P. ricini* with the virus caused almost complete mortality of emerging larvae. The virus was highly species specific. Thermal inactivation point of the virus lay between 95° and 100°C. The virus could withstand weathering for 2 days without loss of virulence and retained substantial infectivity up to 4 days of weathering.

(*Key words:* **granulosis of *Pericallia ricini***)

INTRODUCTION

JACOB *et al.* (1972) reported a granulosis in the larvae of *Pericallia ricini*. Results of studies made on the symptomatology, susceptibility of different larval instars, effect of treating the egg masses with the granulosis virus on the hatching larvae, cross infectivity, thermal inactivation point (TIP) and effect of weathering on the virus are presented in this paper.

MATERIALS AND METHODS

The larvae used in these studies were reared in the laboratory on castor (*Ricinus communis* L.) leaves. A purified suspension of the virus capsules extracted from 300 diseased larvae of *P. ricini* in 3 l of distilled water formed the inoculum. Teepol (0.1 per cent) was used as wetting agent. To infect the larvae under the different experiments the spot feeding technique (JACOB, 1972) was used. 5 μl of the purified capsule suspension were applied to each spot on castor leaves and the larvae which had consumed the entire spotted area of the leaf in 4 hours were transferred individually to sterile plastic cups containing fresh uncontaminated foliage. Control larvae were fed similarly on spots of 0.1 per cent teepol in distilled water.

To study the effect of treating eggs with the virus on the hatching larvae, one-day-old egg masses were surface sterilized in 10 per cent formaline as indicated by THOMPSON & STEINHAUS (1950). They were divided into 4 batches, two batches were painted with the granulosis suspension with a camel hair brush and the other two batches treated similarly with 0.1 per cent teepol to serve as control. On hatching, 50 larvae were collected from each batch and reared individually.

TIP of the virus was studied as described by LATHIKA & JACOB (1974) using 5 ml of virus suspension for each treatment (temperature). To study cross infectivity, larvae of different species were fed with the virus treated foliage of their respective host plants for one day and then transferred to fresh untreated leaves and reared until pupation or death.

To study the effect of weathering on infectivity of the virus a series of 6 mm diameter circles were marked on castor leaves standing on the plants exposed to direct sunlight and 5 μl of virus suspension containing 0.1 per cent teepol placed on each circle. Controls were set with 5 μl of 0.1 per cent teepol. Viral activity of the capsule deposits as affected by sunlight was assayed by plucking the leaves at different intervals after inoculation and feeding the discs to 3rd instar larvae and the response of the larvae observed as usual.

RESULTS

Symptoms of virus infection: The infected larvae became lethargic and showed reduced feeding 4 to 5 days after ingestion of the virus. They exhibited an abnormal feeding behaviour characterised by "spotty feeding' and stopping feeding 2 or 3 days before death. Larvae infected in the early instars appeared smaller in size as disease progressed. In the advanced stages of infection the cuticle became very fragile and ruptured at the slightest pressure liberating the liquefied body contents containing millions of capsules. The dead or dying late instar larvae assumed a typical hanging pose of an inverted 'V'. Incubation period varied from 2 to 14 days.

Larval susceptibility: All larvae under the different instars died ultimately due to the virus infection but the mean incubation period was prolonged from 4.20 days in the 1st instar to 9.48 days in the 5th instar (Table 1). In the 6th instar there was only 36 per cent mortality with a mean incubation period of 9.44 days and the survivors pupated normally and emerged as adults.

The LT_{50} value for the 1st to 5th instars ranged from 3.370 to 8.523 days indicating a gradual decrease in susceptibility as the larvae advanced in age.

Effect of treating egg mass of P. ricini with granulosis virus on the hatching larave: Treating egg masses with the virus was as effective as inoculation of the larvae with the virus causing 90 per cent mortality of emerging larvae with an average incubation of 3.1 days (range 2.5 days).

Thermal inactivation point of the virus: The virus capsules exposed to a temperature range of 50 to 70°C caused cent per cent larval mortality (Table 2). But the infectivity started declining when the temperature was raised to 80°C and above. There was no mortality due to granulosis in the larvae treated with virus exposed to 100°C and all the larvae pupated normally. The thermal inactivation of the virus thus appeared to take place between temperatures 95 and 100°C.

Cross infectivity studies showed that the virus was not infective to caterpillars of *Diacrisia obliqua* and *Utethesia pulchella* (Arctiidae), *Sylepta derogata* (Pyralidae), *Euproctis fraterna* (Lymantridae) and *Sopdoptera mauritia, S. litura* and *Anodevidia* (*Plusia*) *peponis* (Noctuiidae).

The virus remained highly infectious upto 2 days of weathering on castor leaves. Though further exposures caused a decline in virulence it retained 65 per cent infectivity

TABLE 1. Effect of granulosis on different larval instars of *P. ricini*.

Larval Instars	Incubation period (days)		LT_{50} (days)	Regression equation
	Range	Mean		
I	2–7	4.20	3.370	Y = 4.95 x + 239
II	3–9	5.08	4.204	Y = 5.59 x + 1.51
III	3–12	7.04	5.975	Y = 4.64 x + 1.40
IV	4–14	9.12	8.459	Y = 5.80 x – 0.28
V	4–14	9.48	8.523	Y = 5.28 x + 0.08

Note: All the larvae under the different instars died ultimately due to the virus infection.

TABLE 2. Response of 3rd instar larvae of *P. ricini* of inoculation with granulosis virus exposed to different temperatures for 10 minutes.

Temperature (°C)	Time taken for death (days)		Larval mortality due to:		Pupation (%)	Adult emergence (%)
	Range	Mean	Granulosis	Other causes		
50	4–12	7.5	100	Nil	Nil	Nil
60	4–12	7.6	100	Nil	Nil	Nil
70	5–13	8.8	100	Nil	Nil	Nil
80	5–11	7.1	80	Nil	20	20
90	5–11	7.2	50	Nil	50	50
95	5–11	7.3	20	Nil	80	80
100	..	..	Nil	Nil	100	100
Control (active virus)	4–12	7.6	100	Nil	Nil	Nil
Control (without virus)	..	Nil	Nil	Nil	100	100

20 larvae were used for each assay.

TABLE 3. Effect of weathering of granulosis virus on pathogenicity to *P. ricini*.

Biological features	Weathering periods (days)							
	0.0	0.5	1	2	3	4	5	6
Per cent larval mortality.	100	100	95	90	70	65	10	0
Mean no. of days to death.	6.90	5.50	5.55	6.15	6.64	6.92	10.50	0
Per cent pupation	0	0	5	10	30	35	90	100
Per cent adult emergence	0	0	5	10	30	35	90	100
LT (50 days)	5.72	4.70	5.15	5.47	7.59	8.38	..	..

Dosage used was 5 μl of granule suspension/larvae.
LT_{50} is time required for 50 per cent mortality of the test insect.
Number of larvae used in each assay, was 20.

after a period of 4 days. Beyond this duration there was a drastic reduction of infectivity and it was completely inactive after weathering for 5 days.

DISCUSSION

The symptoms of virus infection showed by larvae of *P. ricini* were of the characteristic nature as reviewed by HUGER (1963). The "spotty feeding" of the infected larvae was similar to that reported in *Harrisina brillians* B. and M. & D. (SMITH *et al.* 1956). The increasing resistance as the larvae advanced in age agreed with the general finding that young larvae are more susceptible to granulosis than old ones (TANADA, 1953; SCHMIDT, 1959; SAGER, 1960).

It appeared that mortality of larvae hatching from virus treated eggs was because the larvae ingested the virus along with the portion of egg shells which were generally eaten by them on hatching. A similar observation was made by SMIRNOFF (1961) on nuclear polyhedrosis of the jack pine sawfly *Neodiprion swaineii*.

The TIP of the granulosis virus of *P. ricini* was high (95–100°C) and similar high thermal limits (90–100°C) were reported by PAWAR & RAMAKRISHNAN (1971), LATHIKA & JACOB (1974) and NAIR & JACOB (1976) for polyhedral viruses. The TIP in *P. ricini* exceeded the general limit of 80°C reported for other inclusion body viruses by AIZAVA (1963) and HUGER (1963) indicating that this granulosis virus was comparatively more thermostable. The host-specificity exbibited by the granulosis agreed with the general observation (HUGER, 1963).

The granulosis of *P. ricini* was seen to be much more tolerant to weathering than the polyhedrosis virus studied by LATHIKA & JACOB (1973).

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DEGRADATION OF ALDICARB RESIDUES IN POTATOES[1]

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Pesticidal schedules involving the application of aldicarb (Temik) granules at the rate of 2.0, 3.0 and 4.0 kg al/ha during autumn 1976-77 and at the rate of 1.0 to 5.0 kg al/ha in autumn 1977-78 in the soil at planting time for the control of potato pests, were evaluated in the field experiments, from residues point of view. It was observed that aldicarb, applied upto the doses of 3.0 kg ai/ha at planting time seem to be safe. Processing of raw potatoes through peeling, washing and boiling decontaminated the residues to a considerable extent.

(*Key words:* **aldicarb, Temik, residues, degradation, tolerance limit**)

INTRODUCTION

Aldicarb (Temik) proved to be an excellent pesticide following its granular application at planting in controlling aphids and leafhoppers of potato crop at optimum doses of 1.0–1.5 kg ai / ha (RIZVI *et al.* 1976; VERMA et al., 1976). However, at higher doses (3.0 to 5.0 kg ai/ha), it has also been reported to be effective in controlling nematode infestiation which is one of the serious limiting factors in higher production of healthy potatoes (GILL & KRISHNANANDA, 1977). Since aldicarb is highly toxic and its residues may pose health hazards to the consumers, the residues of aldicarb in potato tubers resulting from its application at optimum and excessive doses have been studied and presented hereunder along with its trend of dissipation during storage and processings.

MATERIALS AND METHODS

Potato variety "Kufri Sindhuri" was raised during autumn 1976–77 and again in autumn 1977–78 in 4.8 × 4.0 m plots at Central Potato Research Station, Jullundur. Each plot contained 8 rows of 16 plants each. The plants were spaced at 60 cm between the rows and 25 cm within the rows. There were four treatments including control during first year and six in the subsequent year experimentation. The experiments were laid out in randomised block design and the treatments were replicated thrice. All the recommended agronomic practices were followed for raising the crop.

Aldicarb (Temik 10 G) granules were applied in the experimental plots at the rate of 2.0, 3.0 and 4.0 kg ai/ha in 1976–77 and at the rate of 1.0, 2.0, 3.0, 4.0 and 5.0 kg ai/ha in 1977–78 at planting.

During autumn 1976–77 the average maximum and average minimum temperatures were 25.45°C (range 15.0°C to 32.9°C) and 9.55°C (range 2.2°C to 20.2°C) respectively. Average relative humidity was 77.15% (range 63.0% to 86.0%). Total rain fall till harvest recorded was 4 mm. However, during autumn 1977–78 average maximum and average minimum temperatures were 21.87°C (range 16.0°C to 32.0°C) and 9.30°C (range 2.1°C to 20°C). Average relative humidity was 85.22% (range 79.8% to 92.3%), total rainfall till harvest was 30 mm. The first crop was irrigated 10 times while the second crop was irrigated 9 times; first irrigation was given one day after planting and remaining irrigations were given at 6 to 11 days intervals. The number of irrigations was reduced in the second crop because of rains during this season.

Potato tuber samples corresponding to each treatment and replicate were collected for residue determination first at normal harvest time i.e. 90

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days of planting. The harvested tubers from different treatments were stored in jute bags separately in store at room temperature (range from 12–30°C). Subsequent tuber samples were drawn from stored potatoes after 30 and 60 days of harvest from both year experiments.

Extraction, clean up and estimation of residues

Extraction of potato tuber samples was done after dividing them in three sets (i) raw tubers i.e. unwashed unpeeled (ii) washed peeled and (iii) washed boiled and peeled. Extraction was also undertaken from the water in which such tubers were boiled to cooking. A representative 100 g sample from each of the treatment and replicate was taken for extraction throughout. The tubers were cut in small pieces and were stripped in 100 ml chloroform by tumbling for one hour with the help of mechanical shaker. The solvent extract was filtered and residue again extracted with a like quantity of solvent for another hour. The two aliquots were combined and concentrated to a known volume in Kuderna Danish Evaporator (KDE). The extract was dried over anhydrous sodium sulphate and stored at low temperature for final analysis.

A suitable aliquot from the extract of the sample was then concentrated to 1 ml in Kuderna Danish Evaporator and then processed through clean up by coagulation method and the residues determined following colorimetric method of JOHNSON & STANSBURY (1966). The recovery experiments were also conducted to see the efficiencies of the extraction, clean up and estimation procedures by fortifying known quantities of aldicarb to raw tubers. An average recovery of 87 to 90% of the aldicarb was found during the experimentation.

RESULTS AND DISCUSSION

Analytical data pertaining to the average (3 replications) residues of aldicarb in potato tubers for the autumn crop 1976–77 experiment, presented in Tabe 1, reveal that aldicarb residues persisted to the extent of 0.55, 0.90 and 1.20 ppm on raw tubers following 2, 3 and 4 kg ai / ha treatments at the time of harvest i.e. 90 days of insecticidal applications. Hereafter samples from stored tubers after one month of the normal harvest i. e. 120 days of treatment resulted into successive reduction in the residues ranging from 62.5 to 100%, bringing down the residues well below the tolerance limit of 1 ppm fixed by EPA (1974) on potatoes from any of the doses applied. Further analysis of the samples drawn from ptatoes stored at room termperature ranging from 12–30°C for 60 days following normal harvest did not leave any detectable quantities of aldicarb residues. The data from different sets of sampls of raw potatoes therefore showed that residues at harvest time itself were below the toleranec limit except from higher dose of 4 kg ai/ha. However, the higher residues resulting from 4 kg ai / ha dose were found to dissipate to the safe limit within next one month of storage of potatoes.

Processing of treated raw tubers by peeling followed by washing, and washing, boiling followed by peeling affected to a great extent on the degradation of residues. Peeling the raw potatoes caused 63 to 65% loss of aldicarb residues whereas boiling followed by peeling was found to remove 94–100% aldicarb. Further analysis of processed tubers from stored potatoes showed by and large total loss of aldicarb.

The residue data from another set of experiment on autumn crop 1977–78 are presented in Table 2 when in the treatment doses were extended from 1 to 5 kg ai / ha. The residues on raw potatoes at harvest time were found to accumulate to the extent of 0.45, 0.62, 0.95, 1.17 and 1.82 ppm respectively. When compared with the previous year experiment the dissipation rate followed almost the same trend in the reduction of residues. It was further confirmed from the analysis of samples drawn from tubers stored for 30 days after harvest i. e. 120 days after treatment, reduction being 55–100%. In the present set of experiment the dose below 4 kg were again found to be safe at harvest from the point of view of tolerance limits but the higher quantities of residues resulting from higher doses of 4 and 5 kg treatments could dissipate below

TABLE 1 Aldicarb residues in potatoes (Autumn 1976–77).

* Average Residues in pm

Days after treatment	Dose kg ai/ha	Unpeeled unwashed potatoes	Peeled washed potatoes	Washed, boiled & peeled potatoes
90	2	0.55	0.18(67.2)	ND(100.0)
(At harvest)	3	0.90	0.31(65.5)	0.05(94.4)
	4	1.20	0.44(63.1)	0.05(95.8)
120	2	ND(100.0)	ND(100.0)	ND(100.0)
(After 30 days of storage)	3	0.17(81.1)	ND(100.00)	ND(100.0)
	4	0.45(62.5)	0.07(94.1)	ND(100.00)
150	2	ND(100.0)	ND(100.0)	ND(100.0)
(After 60 days of	3	ND(100.0)	ND(100.0)	ND(100.0)
storage)	4	ND(100.0)	ND(100.0)	ND(100.0)

* Average of three replications.
Figures in parenthesis denote the per cent reduction of residues.
ND–Not detectable

TABLE 2 Aldicarb residues in potatoes (Autumn 1977–78).

* Average residues in ppm

Days after treatment	Dose kg ai/ha potatoes	Unpeeled unwashed	Peeled washed potatoes	Washed boiled & peeled potatoes	Boiled water of potatoes
90	1	0.45	0.15(66.6)	ND(100.0)	ND(100.0)
(At harvest)	2	0.62	0.23(62.9)	ND(100.0)	ND(100.0)
	3	0.95	0.33(54.7)	0.07(92.6)	0.02(97.8)
	4	1.17	0.48(58.9)	0.15(87.2)	0.07(94.0)
	5	1.82	0.60(67.0)	0.15(91.7)	0.07(96.1)
120	1	ND(100.0)	ND(100.0)	ND(100.0)	ND(100.0)
(After 30 days	2	ND(100.0)	ND(100.0)	ND(100.0)	ND(100.0)
of storage)	3	0.12(87.3)	ND(100.0)	ND(100.0)	ND(100.0)
	4	0.55(55.6)	0.15(87.2)	ND(100.0)	ND(100.0)
	5	0.68(62.6)	0.25(82.6)	ND(100.0)	0.05(972.)
150	1	ND(100.0)	ND(100.0)	ND(100.0)	ND(100.0)
(After 60 days	2	ND(100.0)	ND(100.0)	ND(100.0)	ND(100.0)
of storage)	3	ND(100.0)	ND(100.0)	ND(100.0)	ND(100.0)
	4	ND(100.0)	ND(100.0)	ND(100.0)	ND(100.0)
	5	0.05(92.7)	ND(100.0)	ND(100.0)	ND(100.0)

* Average of three replications. Figures in parenthesis denote the percent reduction of residues.
ND—Not detectable

tolerance limit of 1 ppm only when treated tubers were stored for 30 days. Further analysis of stored tubers from 60 days storage could not show any detectable quantity of residues.

The processing of treated potato tubers again proved to be main factor in reducing the residues to a great extent as reported from previous experiment. Peeling played key role by removing about 55–65% aldicarb residues. Very insignificant quanitities of aldicarb residues could be detected in the pulp of potato. Analysis of water used for boiling the treatd tubers show that it could extract only insignificant residues. Thus a major portion of residues of aldicarb gets accumulated in the skin of tubers which if removed could take care of excessive residues in tubers. Therefore it could be advisable to follow the practice of peeling so as to avoid consumption of contaminated tubers.

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GLOSSAL AND PARAGLOSSAL TRANSFORMATION IN ORDER HYMENOPTERA

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The distal lobes of the labium, the glossa and the paraglossae occur prominently but in simple unmodified state in the hymenopteran families of Pamphiliidae, Xyelidae, Argidae, Tenthredinidae, Diprionidae, Cimbicidae and Cephidae. Then two lines of modifications emerge from the condition occurring in Cephidae and related families, one being represented by Xiphydridae and Siricidae where occurs an inclination towards the fusion of these lobes. This fusion is complete in siricids. The second line is represented by Hymenoptera-Parasitica consisting of Chalcidoidea and Ichneumonoidea, where these lobes maintain their independent identities. The second line further bifurcates. One branch leads through chalcids which form the ancestral stock of many apocritan families such as Scoliidae, Sphecidae, Vespidae, Pompilidae, Eumenidae and Apidae. In the members of these families the glossa is gradually transformed into a prominent tubular form (leading to the formation of proboscis in Honey-bee) while on its either side the paraglossae are reduced into insignificant protuberances which ultimately in apoids occur in the form of mere vestiges. The other branch having ichneumonids at the base is followed by other apocritan families such as Chrysididae, Mutillidae and Formicidae, where glossa and paraglossae remain as prominent distal lobes of the labium of almost equal status. These obsevations collectively bring to light a systematic pattern of directional change which can be considered of significance in establishing the phylogenetic relationships and ramification within the Order Hymenoptera.

(*Key words:* **glossae, paraglossa, Hymenoptera, transformations, phylogenetic relationships**)

INTRODUCTION

What follows is one of the links composing an extended work tracing the evolutionary trends within the entire range of Order Hymenoptera. This particular work deals with the structural modifications of glossa and paraglossae, the distal lobes of the labium, and their arrangement into a serial pattern for establishing the phylogenetic relationships of the various families within this insect order. Earlier, thus far, no such comprehensive studies have been undertaken to bring out the series of evolutionary changes affecting the distal lobes of the labium.

However, otherwise there are numerous references available in the morphological literature about the labial lobes in connection with their exploration on ontological basis. Rather whatever is worth knowing about them ontologically finds ample mention here and there. Some of such important authors who worked exhaustively on this problem include, VAN DINE (1905), LIU (1925), BIRD (1926), SNODGRASS (1925, 1935), REEKS (1937), ROSS (1937), ALAM (1951), ARORA (1953, 1956), RIVARD (1955), MATSUDA (1957), BRACKEN (1961), TAIT (1962), WONG (1963), DHILLON (1966) and GOTWALD (1969). Their works though hardly discuss the modifications of these

lobes in relation to those occurring in their relatives, distant or near. Such observations with their systematic corollary are vividly missing from the literature. The present work is indeed an attempt in this direction and it is based on the observations made on the various members belonging to 22 families of Order Hymenoptera.

MATERIAL AND METHODS

To carry on the present study almost all the hymenopterans representing all the superfamilies of Suborder Apocrita, were collected from the Punjab and Himachal Pradesh during the months of September and October, 1975 and the material so collected was preserved in 80% alcohol. However, the representatives of the various families of Suborder Symphyta with the exception of Megalodontidae and Orussidae, were supplied by the Biosystematic Research Institute, Canada, and Zoological Survey of India, Calcutta. The specimens provided by them were in a dry state, which were softened after keeping them in 2% KOH for about six hours. Pigmented specimens were bleached with 0.5% KOH after keeping them in the latter for about 6 days. Diagrams were drawn with the help of Graph eye-piece.

OBSERVATIONS AND DISCUSSION

Ordinarily there are no grounds to compare the simple globular and fluffy structure consisting of glossa and paraglossae of the lower symphytans, with the highly specialised proboscis of the *Xylocopa lemuiscapa* (Apoidea), because structurally these are very widely separated from each other. Thus, it seems somewhat difficult to assume that such simple and generalized forms of glossa and paraglossae have given rise to such a complex and specialized forms of proboscis of the higher apocritans, until and unless comparative study of these structures is made. And the present studies are an attempt to sort out evolutionary mediaries, between the simple and complex forms of this central portion of the hymenopteran mouth parts.

To start with, the glossa and paraglossae in simple and unmodified state occur in most of the symphytans such as in *Acantholyda maculiventirs* (Fig. 1) (Pamphiliidae), *Xyela bakeri* (Fig. 2) (Xyelidae), *Arge clavicornis* (Fig. 5) (Argidae), *Cimbex americana americana* (Fig. 3) (Cimbicidae), *Neodiprion abietis* (Fig.8) (Diprionidae), *Tenthredo verticalis* (Fig. 4) (Tenthredinidae) and *Cephus* (*Cephus*) *cinctus* (Fig. 7) (Cephidae). In all these glossa and paraglossae are equally developed, however, differing in shapes and other minor details. In *Acantholyda, Xyela, Arge* and *Neodiprion* these are round at their tips and also being slightly longer than broad, and are beset with numerous microscopic sensory setae which are more prominent and longer along their distal margins. In *Cimbex* and *Cephus* the glossa resembles with what is described above. On the other hand the paraglossae are roughly rectangular in case of *Cimbex* and almost triangular and pointed towards the tips in *Cephus*. In both these cases, both glossa and paraglossae are beset with numerous small sensory setae. In all these insects the glossa and paraglossae are altogether free and their sides do not either show any trace of fusion or else any closer approximation. Similar observations have also been made on *Zarae inflata* (Cimbicidae), *Pristiphora cincta, Pachyprotasis versicolor, Pachyprotasis brunetti* and *Tomostethus* (*Eutomostethus*) *assomensis* (Tenthredinidae). These findings are further substantiated by the works on different members of Suborder Symphyta by VAN DINE (1905), BIRD (1926), SNODGRASS (1925, 1935), REEKS (1937), ROSS (1937), ARORA (1953, 1956), RIVARD (1955), MATSUDA (1957), BRACKEN (1961), WONG (1963) and DHILLON (1966). However, ROSE (1937) in *Macroxyela ferruginea* reported a condition more primitive than the above indicating that in this case glossa is completely absent and instead a membrane is stretched between the bases of the paraglossae.

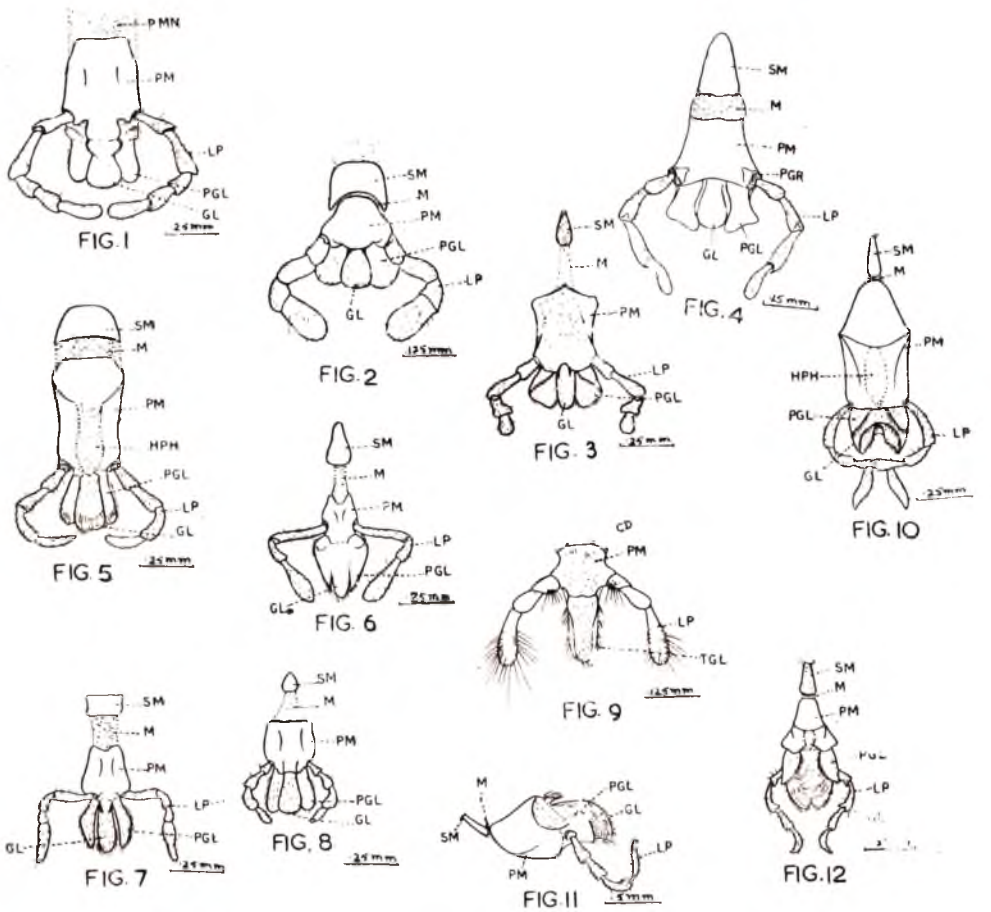
A slightly different condition is represented in *Xiphydria mellipes* (Fig. 6) (Xiphydridae). In this case the paraglossae and glossa maintain their usual identities but differing in shape. These taper distally and also along their mesal margins the basal halves are fused with one another thereby forming a somewhat compact structure. Their entire dorsal surface is covered over by a scattered growth of fine sensory microscopic setae. Similar condition has also been reported by ARORA (1956) in *Xiphydria prolongata*. However, TAIT (1962) in *Perga affinis affinis* (Pergidae) has reported a fusion between paraglossae and glossa which is of slightly greater magnitude than that of the *Xiphydria mellipes* (Xiphydridae) as mentioned above. In this case the paraglossae are very much reduced as compared to the glossa.

A highly modified stage exhibiting fusion of still greater magnitude, is represented in *Sirex cyaneus* (Sircidae) (Fig. 9), in which the glossa and paraglossae are completely fused forming a single compact setiferous conical structure or the "totaglossa" of ARORA (1956). This appears to be a characteristic feature of all the members of the family Siricidae as the similar conditions have also been reported by Ross (1937) in *Urocerus* (Siricidae), Ross (1948) in *Tremex columba* (Siricidae) and ARORA (1956) in *Urocerus gigas* (Siricidae).

Hymenoptera-Parasitica which diverged from the siricids somewhere at the level of cephids represents two different and distinct forms of the terminal lobes of the prementum. In *Sycoscapter stabilis* (Fig. 13) (Chalcidoidea), median glossa is quite prominent and it completely dominates, but the slenderer paraglossae lying on its either sides. However, there is no sign of fusion between the paraglossae and glossa. These findings are further substantiated by the similar studies made on many other chalcids like *Blastophaga masoni* (Agaonidae), *Walkerella temeraria* (Torymidae) and *Sycophila decatomoides* (Eurytomidae).

In the representatives of superfamily Ichneumonidea such as in *Netelia kashmirensis* (Fig. 10) and *Trachysphyrus* sp. (Figs. 11 & 12) the glossa is again quite prominent but it is bifurcated at its tip. It is thick and fluffffy. In comparison the paraglossae are small flap like structures which lie closely applied laterally to the basal halves of the glossa. The sensory setae are generally scattered all over them. However, these are prominently displayed along the mesal margin which give them a comb like appearance. The occurrence of reduced paraglossae and dominating median glossa has also been described by ALAM (1951) who lables the median glossa as the lingua in *Steenobracon deesae* (Braconidae).

This stage forms the basis on which are further built the trends of lingual modifications represented in the members of the families of Chrysididae, Mutillidae and Formicidae. In *Chrysis indogolea* (Fig. 14), *Sima rufonigra* (Fig. 19) and *Dorylus labiatus* (Fig. 21) the glossa and paraglossae almost resemble with the condition occurring in ichneumonids. The glossa is not bifurcated distally but it is quite prominent otherwise. Its entire dorsal surface is covered with very minute horizontal ridges which are further provided with sensory setae. However, in *Mutilla* sp. (Fig. 18) and *Camponotus camelinus* (Fig. 20) glossa is oval which distally enclose a circular area that appears to be sensitive than its general surface. This observation is based on the fact that this area is specifically rich in ridges and sensory setae. In these cases though lingular modification is evident yet the tendency of forming a proboscis is missing. Similar structure of the glossa and paraglossae have also been described by WHEELER (1910)



Posterior view of the labium of: 1. *Acantholyda maculiventris;* 2. *Xyela bakeri;* 3. *Cimbex americana americana;* 4. *Tenthredo verticalis;* 5. *Arge clavicornis;* 6. *Xiphydria mellipes;* 7. *Cephus* (*Cephus*) *cinctus;* 8. *Neodiprion abietis;* 9. *Sirex cyaneus;* 10. *Netelia kashmirensis;* 11. Side view of the labium of *Trachysphyrus* sp.; 12. Anterior view of the labium of *Trachysphyrus* sp.:

and GOTWALD (1969) in the different formicids.

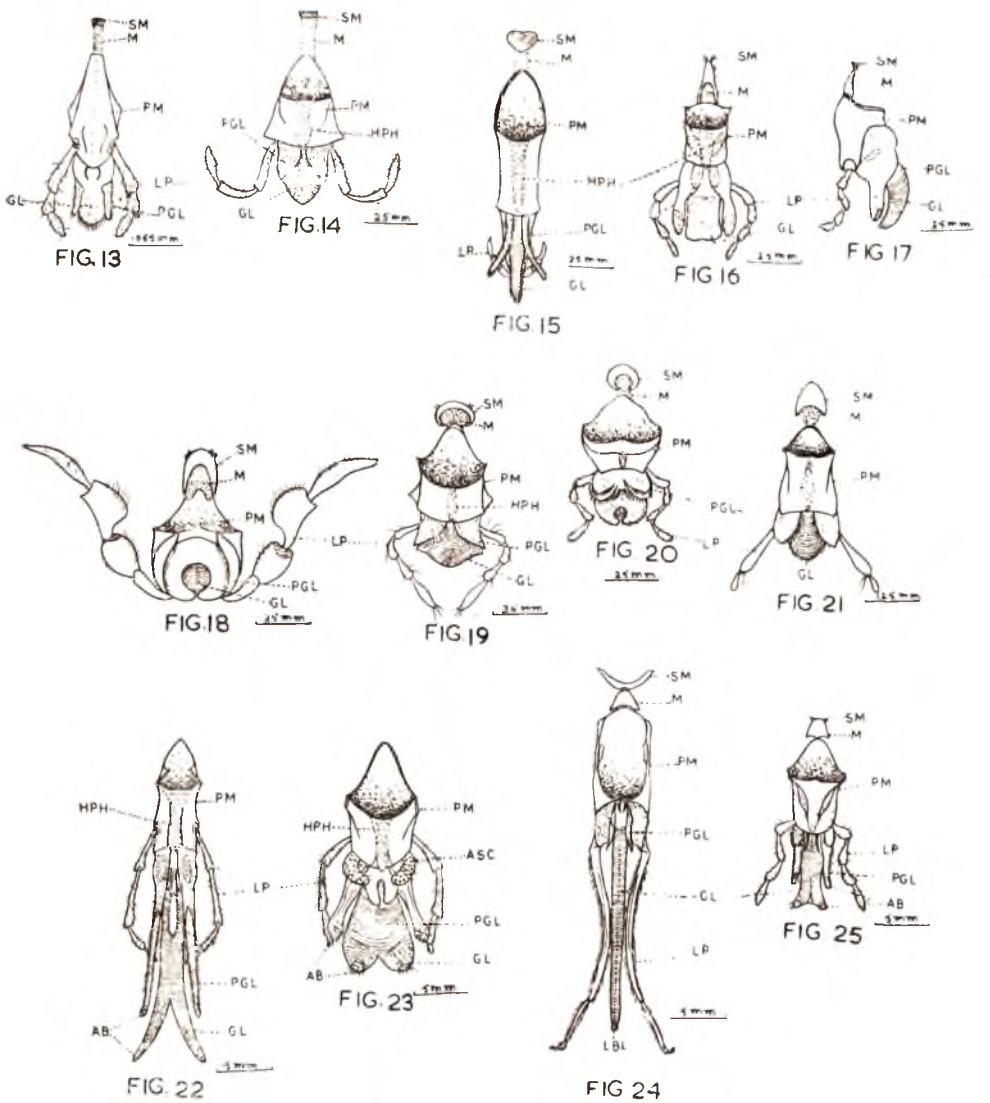
The tendency of forming a proboscis manifested in *Xylocopa lemuiscapa* (Apoidea) where the paraglossae are extremely reduced but the glossa appears in the form of an extended structure, clearly occurs in the members of the family Scoliidae, Sphecidae, Vespidae, Pompilidae and Eumenidae and the chalcids form the ancestral stock for such modifications.

In *Scolia quadripustulata* (Fig. 15) (Scoliidae) the glossa is prominent, and it is considerably elongated in the form of a proboscis. Whole of its dorsal surface is provided with horizontal but shallow alternative grooves and ridges which are further clothed by a rich growth of sensory setae. Paraglossae are also similarly elongated but they are shorter in length, and they lack the horizontal grooves and ridges, though they are covered over with a profuse growth of sensory setae.

In the representatives of the families of Sphecidae, Vespidae and Pompilidae such as in *Scelephron intrudens* (Fig. 16) *Stizus vespiformis* (Fig. 17), *Vespa Orientalis* (Fig. 23) and *Calicurgus* sp. (Fig. 25) the glossa is prominent while the lateral paraglossae are reduced. In sphecids only the tips of the paraglossae are provided with sensory areas which are missing though from glossa. In case of wasps and pompilids the glossa is terminally bifurcated and both the lobes are provided with semicircular sensory areas or acroglossal buttons of LIU (1925) at their tips (Fig. 23 & 25). Besides these, glossa is also provided with horizontal ridges. On the other hand the paraglossae are meagre in size though they are covered by setae but they lack the ridges. These modifications of course indicate a clear cut tendency towards forming a distinct proboscis. Similar structure of the glossa and paraglossae has also been described by LIU (1925). These modifications are further pronounced in the members of family Eumenidae. In *Eumenes dimidiatepennis* (Fig. 22) the glossa is very much elongated, and excepting for the fact that it is bifurcated at its tip, it otherwise resembles considerably with that of the proboscis of *Xylocopa lemuiscapa* (Fig. 24). Its dorsal surface is provided with a series of horizontal ridges which are also studded with rich growth of sensory setae. Their paraglossae are also elongated, but being of thinner and smaller disposition they are completely dominated by the glossa. Their tips and those of the glossa are provided with sensory areas or "acroglossal buttons" of LIU (1925) (Fig. 22).

The highest level of modifications is revealed by the members of superfamily Apoidea. In *Xylocopa lemuiscapa* (Fig. 24) the median glossa has become a long cylindrical and solid structure which is marked with tranverse ridges. These ridges are further provided with a rich growth of sensory setae. At the tip of glossa there is demarcated a ball like rounded structure which has been named as "labellum" by SNODGRASS (1925) and DELONG & BORROR (1970) in honey bee and *Xylocopa* sp. respectively. However, this sensory structure can be safely compared with the acroglossal buttons present in case of wasps. The paraglossae are in the form of small flaps lying on either side of the base of the proboscis (glossa). Their extremely reduced size as compared to those of the wasps, indicate their tendency towads being lost altogether. Similarly reduced paraglossae have also been reported by SNODGRASS (1925, 1935) and DELONG & BORROR (1970) in honey bee and *Xylocopa* sp. respectively. However, in the solitary bees, as reported by Snodgrass (1925) the glossa is not as developed as in case of *Xylocopa* sp. or the honey bee. This stage can be taken as an intermediate one, between Eumenidae and social apoids.

This study provides a clear glimpse of the various lines of modifications which lead to the formation of different forms of glossa and paraglossae, as are represented in siricids, formicids and apoids. This diversified representation of the modifying trend also gives a clue about the path that evolution has followed, which is not in the form of a straight line but in a zigzag form.



13. Posterior view of the labium of *Sycoscapter stabilis;* 14. Anterior view of the labium of *Chrysis indogolea;* 15. *Scolia quadripustulata;* 16. *Scelephron intrudens;* 17. Side view of the labium of *Stizus vespiformis;* Anterior view of the labium of: 18. *Mutilla* sp.; 19. *Sima rufonigr;* 20. *Camponotus camelinus;* 21. *Dorylus labiatus;* 22. *Eumenes dimidiatepennis;* 23. *Vespa orientalis;* 24. *Xylocopa lemuiscapa;* 25. *Calicurgus* sp.

ABBREVIATIONS USED

AB—Acroglossal buttons; ASC—Additional sclerite; CD—Cardo; GL—Glossa; HPH—Hypopharynx; LBL—Labellum; LP—Labial palp; M—Mentum; PGL—Paraglossa; PM—Prementum; PMN—Postmentum; SM—Submentum; TGL—Totaglossa.

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THREE NEW SPECIES OF GREENIDEINAE FROM MANIPUR STATE (INDIA)

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Three new species, viz., *Brevitrichosiphon nugsireiae*, *Eutrichosiphum jugeshwari* and *Eutrichosiphum manipurense* of the subfamily Greenideinae are described from Manipur (India). Systematic position of the new species is discussed.

(*Key words:* **aphid taxonomy, morphology, new species, India)**

INTRODUCTION

Examination of the aphids belonging to the subfamily Greenideinae collected from Manipur has revealed the existence of three new species,viz., *Brevitrichosiphon nungsireiae*, *Eutrichosiphum jugeshwari* and *Eutrichosiphum manipurense* which are described here.

The specimens are now in the collection of the Aphid Research Unit, Entomology Laboratory, Department of Zoology, University of Calcutta, India.

1. **Brevitrichosiphon nungsireiae,** sp. nov.

Apterous viviparous female (Fig. 1): Body pear-shaped, about 1.29–1.32 mm long with 0.68–0.72 mm as maximum width. Head pale brown; frons slightly convex; dorsal cephalic hairs short to long with blunt, acuminate and fine apices, longest hair about 2.11–2.50 × b.d.III, shortest hair about 0.40–0.50 × the mentioned diameter. Antennae 5 segmented; concolorous with head excepting segment III and IV which are slightly paler, about 0.36–0.38 × body; flagellum gradually distinctly imbricated from base to apex excepting basal 9.46 portion of segment III which is smooth; flagellar hairs like dorsal cephalic ones, longest hair on segment III about 2.20–2.50 × b.d. III and shortest one about 0.35–0.50 × the mentioned diameter; p.t. about 1.30–1.33 × base of antennal segment V. Rostrum reaching middle of body, segments 4+5 of rostrum about 3.24–3.50 × h.t. 2 and segment 4 about 5.40–6.36 × segment 5, with short secondary hairs. Abdominal dorsum sclerotized, dark brown, wrinkled; short and long dorsal abdominal hairs occur intermingled. Longer hairs being with acuminate, slightly furcated or slightly spatulate apices, shorter hairs thorny or with apices like the longer hairs; venter with spinules laterally, posteriorly and on anterior margin leaving the median area free; longest hair on the anterior tergites about 2.50–2.66 × b.d. III and shortest one about 0.33–0.45 × the mentioned diameter; each of 7th and 8th tergites with two long hairs with acuminate apices, these about 2.83–3.50 and about 4.0–4.50 ×

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Some of the abbreviations used in the text are: p.t.–processus terminalis; b. d. III–basal diameter of antennal segment III; u. r. s.–Ultimate rostral segment; h. t. 2–second segment of hindtarsus and F. T. C.–first tarsal chaetotaxy.

the mentioned diameter respectively. Siphunculi, blackish brown, except the very apex which is slightly paler, barrel shaped, about 0.19–0.20×the body, with spinules in transverse rows, about 2.57–2.71 × its maximum width, at base about 1.5 times, at middle about 3.0–3.5 times and at apex about as thick as the middle diameter of hindtibiae, hairs on siphunculi with

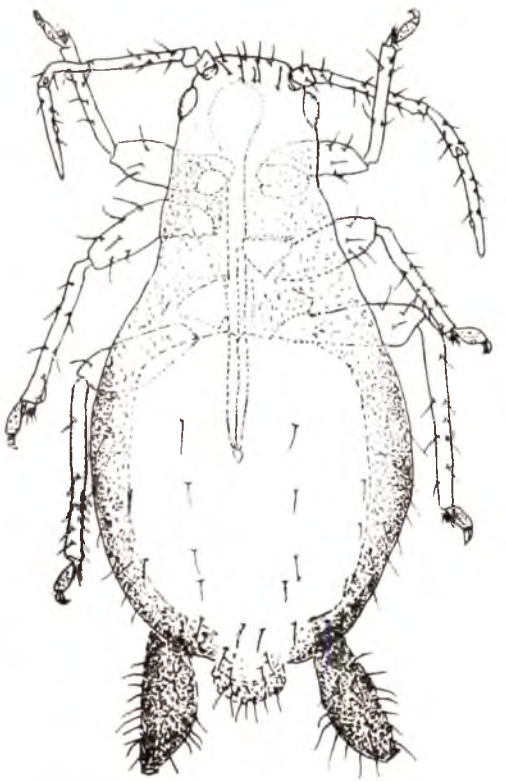

Fig. 1. *Brevitrichosiphon nungsireiae* sp. nov. Apterous viviparous femae.

very short to very long, longer hairs with acuminate to bluntish apices, shorter ones with acuminate to bluntish or slightly bifid apices; longest hair about 2.13–2.33 × basal diameter of siphunculi and shortest one about 0.30–0.50×the mentioned diameter. Cauda semioval, with (?) 2 hairs. Legs pale brown; femora with sparse spinulose striae ventrally on the inner margin, tibiae smooth; femoral and tibial hairs like dorsal abdoninal hairs: F.T.C. 7,7,7.

Measurements of the holotype in mm: Length of body 1.29, width 0.68; antenna 0.47, antennal segments III:IV:V 0.12: 0.08: (0.08+0.11); segments 4+5 of rostrum 0.26: (0.22+0.04); h. t.2 0.07; siphunculus 0.26; width of siphunculus at base 0.04, at middle 0.09, at apex 0.02; middle diameter of hindtibia 0.02.

Collection data: **Holotype:** 1 apterous viviparious ♀, INDIA: MANIPUR: Sanakeithal (*c* 845.0 m) from *Quercus* sp. (Fagaceae), 16.xii.1971, coll T. K. Singh.

Paratype: 1 apterous viviparous ♀ with the same data as for the holotype.

Remarks: This new species comes close to only other known species, *Brevitrichosiphon mukherjee* Raychaudhuri, Ghosh, Banerjee and Ghosh but differs from it in having longer rostrum, longer siphunculi and longer antennal and body hairs.

2. Eutrichosiphum jugeshwari, sp. nov.

Apterous viviparous female (Fig. 2). Body elongated, about 2.3–2.63 mm long with 0.92–0.97 mm as maximum width. Head pale brown; anterior dorsal cephalic hairs long, posteriorily with bluntish to acuminate apices, a few shorter ones with apices similar to anterior ones, also occur. Antennae 5 segmented coloured like the head but the very apex of segment IV and a little more than distal; 0.50 portion of segment V, brown, about 0.51–0.60×the body; flagellum more distinctly imbricated apicad; p. t. about 1.07–1.14×base of segment V; flagellar hairs with acuminate to bluntish apices; longest hair on segment III about 1.80–2.80 × basal diameter of the segment, shortest one about 0.45–0.60×the mentioned diameter. Rostrum reaching hindcoxae; segments 4+5 of rostrum about 1.53 – 1.7×h.t. 2; segment 4

about 3.90–4.66 × segment 5, with about 6 secondary hairs. Abdominal dorsum nearly pale, spinulose antero-laterally; dorsal abdominal hairs short and long and mostly with furcated apices, longest hair on the anterior tergites about 1.68–2.30 × b.d. III; 7th tergite with 2 stout hairs which are with

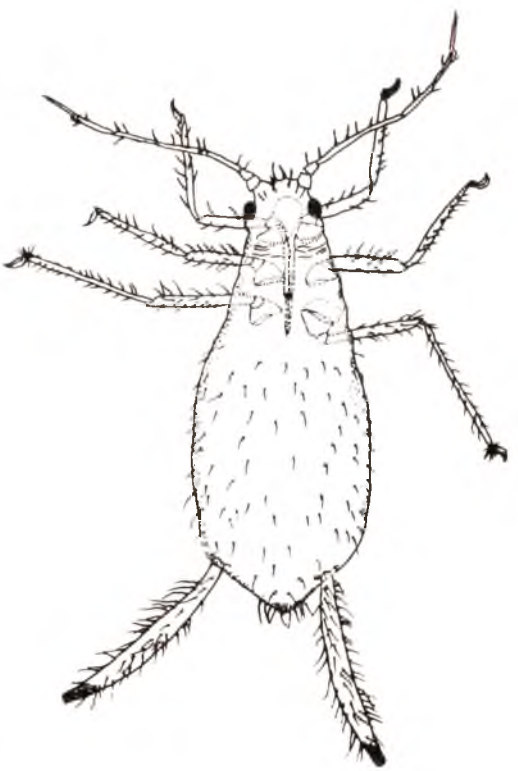

Fig. 2. *Eutrichosiphum jageshwari*, sp. nov. : Apterous viviparous female.

acuminate apices, and about 2.63 × b.d.III; 8th tergite also with two long hairs and these about 3.0–3.54 × the mentioned diameter. Siphunculi pale brown except the nearly black apex, spinulose, curved outwards, about 0.44–0.51 × body, about 6.91–10.0 × its maximum width; at base about 2.30–3.50 ×, at middle about 3.60–5.50 × and at apex about 1.30–2.0 × middle diameter of hindtibia; spiphuncular hairs long with fine apices and a few shorter ones also with similar apices: longest one being about 1.40–2.09 × the basal diameter of siphunculi and shortest one about 0.30–0.56 × the mentioned diameter. Cauda helmet shaped, about 8 hairs. Legs pale, femora with faint spinulose striae ventrally on at least distal 0.50 portion and tibiae smooth with a few rows of spinules near apex, apical tibial hairs not very different from other tibial hairs; F.T.C. 7.7.7.

Measurements of the holotype in mm: length of body 2.63, width 0.92; antenna 1.19, antennal segments III:IV:V 0.47: 0.22: (0.18+0.19); segments 4+5 of rostrum 0.15: (0.12+0.03); h.t.2 0.09; siphunculus 1.11: width of siphunculus at base 0.06, at middle 0.11 at apex 0.04; middle diameter of hindtibia 0.02.

Collection data: **Holotype** 1 apterous viviparous ♀: INDIA: MANIPUR: Nungbi (*c* 2135.0 m) from *Quercus* sp. (Fagaceae), 11.xii.1972. Coll. T.K. Singh.

Paratypes: 4 apterous viviparous ♀♀ and 5 nymphs, with same data as for the holotype.

Remarks: The new species approaches to *Eutrichosiphum quercifoliae* Raychaudhuri, Ghosh, Banerjee and Ghosh in having smooth median area on abdominal dorsum and in the ratio of siphunculus to body but can be differentiated from *quercifoliae* by shorter rostrum, ratio of segments 4+5 of rostrum to h.t.2, and also the ratio of segment 4 to segment 5 of rostrum.

3. **Eutrichosiphum manipurense**, sp. nov.

Apterous viviparous female (Fig.3); Body about 1.71–2.08 mm long with 0.90–1.0mm as maximum width. Head pale, with hardly developed lateral frontal tubercles; dorsal cephalic hairs long and stout with acuminate to bluntish apices. Antennae pale, 5 segmented, with the apices of segment IV, distal 0.5 portion of segment V brownish,

about 0.46—0.59 × body; p.t. about 1.40—1.70 × base of segment V; flagellum gradually more distinctly imbricated apicad; flagellum with short and long hairs which are with acuminate to bluntish apices, longest hair on antennal segment III about 1.78—2.36 × basal diameter of the segment, shortest one being about 0.36—0.58 × the mentioned diameter. Rostrum reaching hindcoxae;

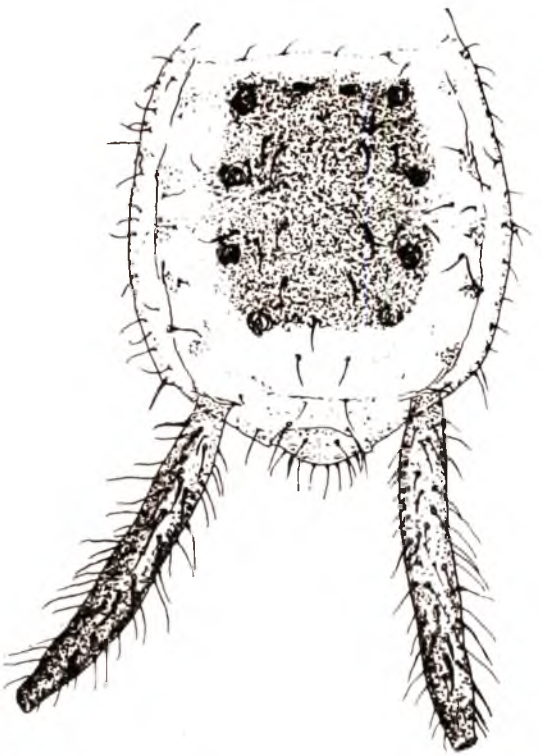

Fig. 3. *Eutrichosiphum manipurense*, sp. nov. Apterous viviparous female, abdominal dorsum.

segments 4+5 of rostrum about 1.32—1.48 × h.t. 2, segment 4 about 3.1–4 × segment 5, with about 4 secondary hairs. Thoracic tergites slightly rugose, sometimes such rugosity appears as small warts. Abdominal dorsum pale, slightly rugose, without any spinule and with a brownish median patch (Fig. 3) extending on tergites 2–4, besides some scattered muscle plate like structure arranged segmentally, pleurally on tergites 2–5, on each of anterior tergites, about 8–10 hairs present; dorsal abdominal hairs stout, stiff and sparse with blunt apices, longest hair on anterior tergites about 1.30—1.83 × b.d. III; 7th tergite with 4 stout and stiff hairs which are about 1.64—2.18 × b.d. III; 8th tergite with 2 similar hairs which are about 2.16–3.09 × the mentioned diameter. Siphunculi pale brown but gradually becoming darker apicad so that distal 0.33 portion appears black, indistinctly reticulated with transverse hexagonal cells at base and with transverse rows of spinules, about 5.30–6.60 × its maximum width, at base about 3.0–3.50 ×, at middle about 4.0–5.50 × and at apex about 2.0–2.50 × middle diameter of hindtibiae; hairs on siphunculi susually all long with fine apices, a few shorter ones also present with similar apicess; longest one being about 0.32–0.6 × the mentioned diameter. Cauda helmet shaped, with about 6–8 hairs. Legs pale, femora with a transverse row of spinules ventrally on distal 0.50 portion; tibiae imbricated near apex; the apical tibial hairs not much different with other tibial hairs; F.T.C. 7.7.7.

Measurements of the holotype in mm: length of body 1.82; width 0.94; antenna 1.08; antennal segments III: IV: V 0.47: 0.15: (0.13+0.19); segments 4+5 of rostrum 0.13: (0.10+0.03); h.t.2.0.08; siphunculus 0.83; width of siphunculus at base 0.08; at middle 0.11; at apex 0.05; width of hindtibia at middle 0.02.

Collection data: **Holotype:** 1 apterous viviparous ♀; INDIA: MANIPUR: Pangyang, from *Quercus* sp. (Fagaceae), 11.xi.1972. coll. T.K. Singh

Paratypes: 2 apterous viviparous ♀♀ with the same data as the holotype; 6 apterous viviparous ♀♀, 6 nymphs, Manipur, Kangehup, from *Quercus* sp. (Fagaceae), 13.xi.1971, coll. T. K. Singh 3 apterous viviparous ♀♀, 5 nymphs, Manipur.

Moreh, from *Quercus* sp. (Fagaceae 17.xi.1972; coll. T.K. Singh; 4 apterous viviparous ♀♀ and many nymphs, Manipur, Churachandpur, from *Quercus* sp. (Fagaceae), 13.xi.1976, coll. D. Ray chaudhuri.

Remarks: This new species in having smooth abdominal dorsum and sparsely arranged hairs with blunt apices approaches to *Eutrichosiphym pyri* Chakrabarti, Ghosh and Raychaudhuri but it stands in sharp contrast from *pyri* by the presence of abdominal brownish median patch, longer and dark siphunculi, smaller ratio of u.r.s. to h.t. 2 and also that of segment 4 to segment 5 of rostrum besides other characters. Moreover, the new species differs from *pyri* in having different host association.

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NEW SPECIES OF *ALEBROIDES* MATSUMURA FROM INDIA AND TIBET (AUCHENORRYNCHA, CICADELLIDAE, TYPHLOCYBINAE)

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Alebroides haedus **sp. n. from Tibet and** *A. clavatus* **sp. n.,** *A. falcatus* **sp. n.,** *A. fumosus* **sp. n.,** *A. montanus* **sp. n., and** *A. luteus* **sp. n., from India are described and figured. A key to the species of** *Alebroides* **from India and Tibet is also included.**

(*Key words: Alebroides haedus, A. clavatus, A. falcatus, A. fumosus, A. montanus, A. luteus, Empoasca nigroscutellata, Typhlocyba spectra*)

The genus *Alebroides* was described by Matsumura (1931). Dworakowska (1977) revised the genus and transferred the Indian species, *Empoasca nigroscutellata* Distant and *Typhlocyba spectra* Distant to it. In the present study five new species from India and one from Tibet are described.

The types of new species are deposited at the Polish Academy of Sciences, Krakow (PAS), Punjab Agricultural University, Ludhiana (PAU), Staatliches Museum für Tierkunde in Dresden, D. D. R. (SMT), British Museum (Natural History), London (B. M.), University of Agricultural Sciences, Bangalore (UAS) and at the Zoological Survey of India, Calcutta (ZSI) as indicated in the description of certain species. The depository of the type is mentioned at the end of description of each species.

1. Alebroides haedus sp. nov. (Fig. 1–8)

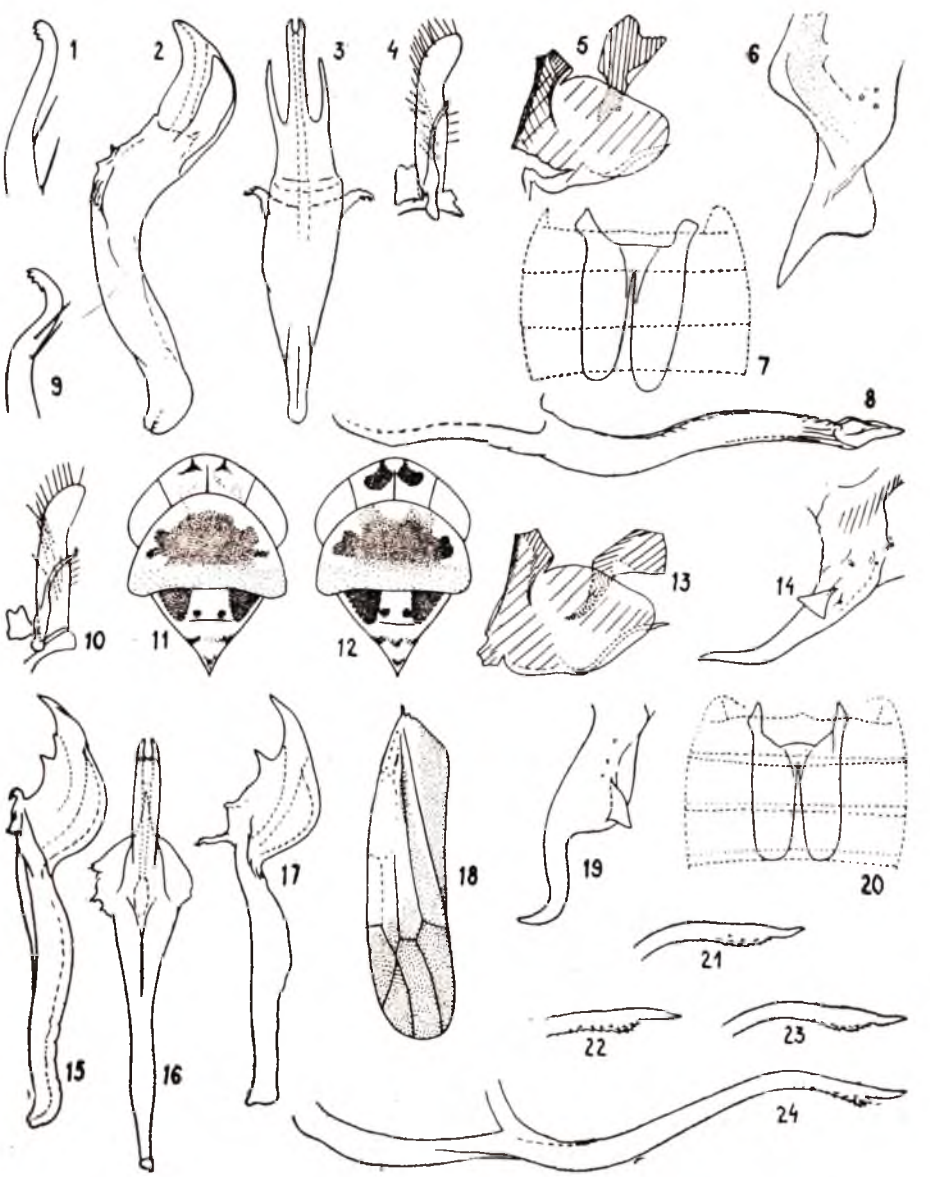
Ground colour of body testaceous–grey. Eyes brown. Whitish pattern on head consists of a large patch in the centre of frons, patches covering interocular areas, two semicircular broad lines surrounding ocelli on their inner sides and oblique lines joining the semicircular lines in the midline of vertex (but not reaching its base). Central patch at anterior margin of pronotum, centre of scutum and whole scutellum whitish. Forewing semitransparent and light testaceous, without any pattern.

Anal tube appendage short and broad (Figs. 5,6). Pygophore appendage slightly sinuated, subapically broadened and ornamented with short and thick ledges (Fig. 8). Paramere very slim at apex (Fig. 1). Penis stem compressed laterally, provided with lamellate lateral appendages at base (Figs. 2, 3). Abdominal tergites slightly infuscated; abdominal apodemes narrowing apically (Fig. 7).

Length: ♂4.4–4.5 mm.

Holotype: ♂ Tibet, Yatung, 10,000 feet. 17–20. ix. 1927, F. M. Bailey; deposited in ZSI, **Paratype** ♂: same collection data as for holotype but collected on August. 1927, deposited in ZSI.

A. haedus can be separated from other species of *Alebroides* by the presence of a pair of lateral appendages at the base of penis.



Alebroides haedus sp.n. (Figs. 1–8). 1–Apical part of paramere; 2–Penis, side view; 3–Penis, posterior view; 4–Proportions of subgenital plate, paramere, connective and ninth abdominal sternite; 5–Scheme of proportions and Pigmentation of Pygophore side and anal tube appendage; 6–Anal tube appendage; 7–Abdominal apodemes; 8–Pygophore appendage.

Alebroides fumosus sp. n. (Figs. 9–24). 9–Apical part of paramere; 10–Proportions of subgenital plate, paramere, connective and ninth abdominal sternite; 11–Head and throax of male; dorsal view; 12–Head and thorax of female dorsal view; 13–Scheme of proprotions and pigmentation of pygophore side and anal tube appendage; 14–Anal tube appendage; 15–Penis; side view; 16–Penis; posterior view; 17–Penis; side view; 18–Forewing of male; 19–Anal tube appendage; 20–Abdominal apodemes; 21 to 24–Pygophore appendage.

2. Alebroides fumosus sp. nov. (Figs.9–24)

Vertex slightly produced in the middle of female (Fig. 12) and almost parallel–sided in male (Fig. 11). Ground colour of upper surface of body sandy–testaceous. There are brownish patches on anterior part of vertex, larger in female. Basal triangles and sometimes patches on scutellum brownish. Almost whole pronotum occupied by a large olivaceous–grey patch. Hindmargin of pronotum broadly grey. Face citrine–yellow. Eyes blackish and sandy–testaceous. Coronal suture, sutures between anteclypeus and frontoclypeus and between scutum and scutellum, blackish–brown. A large area on forewing (spotted in Fig.18) light browish–grey; ground colour light testaceous. Abdominal sclerites blackish. Lateral margins of valvulae (especially at apices) blackish–brown, sometimes whole valvulae dark.

Anal block and abdominal sclerites very dark. Anal tube appendage curved at tip, provided with a small triangular lamella directed laterad. In slides the lamella is bent back or forward (Figs. 14.19). Pygophore appendage thin, long (Figs. 13, 24), it is sinuated and ornamented with teeth in apical part (Figs. 21–24). Penis compressed laterally, well sclerotized, provided with step–like extensions on its dorsal side (Figs.15–17). Abdominal apodemes reaching upto the fifth abdominal sternite (Fig. 20).

Length: ♂4.0 – 4.1 mm, ♀4. 0 – 4.3 mm.

Holotype ♂and **paratypes** 3♂♂and 5♀♀ INDIA, WEST BENGAL, Darjeeling, ex grasses, 24. iv. 1978, coll. I. Dworakowska.

The holotype and part of paratypes are deposited at PAS. Other paratypes are at the BM and SMT.

Alebroides fumosus can be distinguished from other species by its pygophore appendage which is thin and long ornamented with teeth near apex.

3. Alebroides falcatus sp. nov. (Figs. 25–32)

Externally very similar to *A. montanus* sp. n. but vertex more rounded and with upper side of body more yellowish. Both specimens at our disposal are teneral. Apices of valvulae infuscated.

Male genital apparatus resembles that of *A. hachijonis* Matsumura but anal tube appendage smaller (Figs. 28, 29), pygophore appendage falcate (Figs. 29, 30, 31) and penis narrower (Figs. 25, 26).

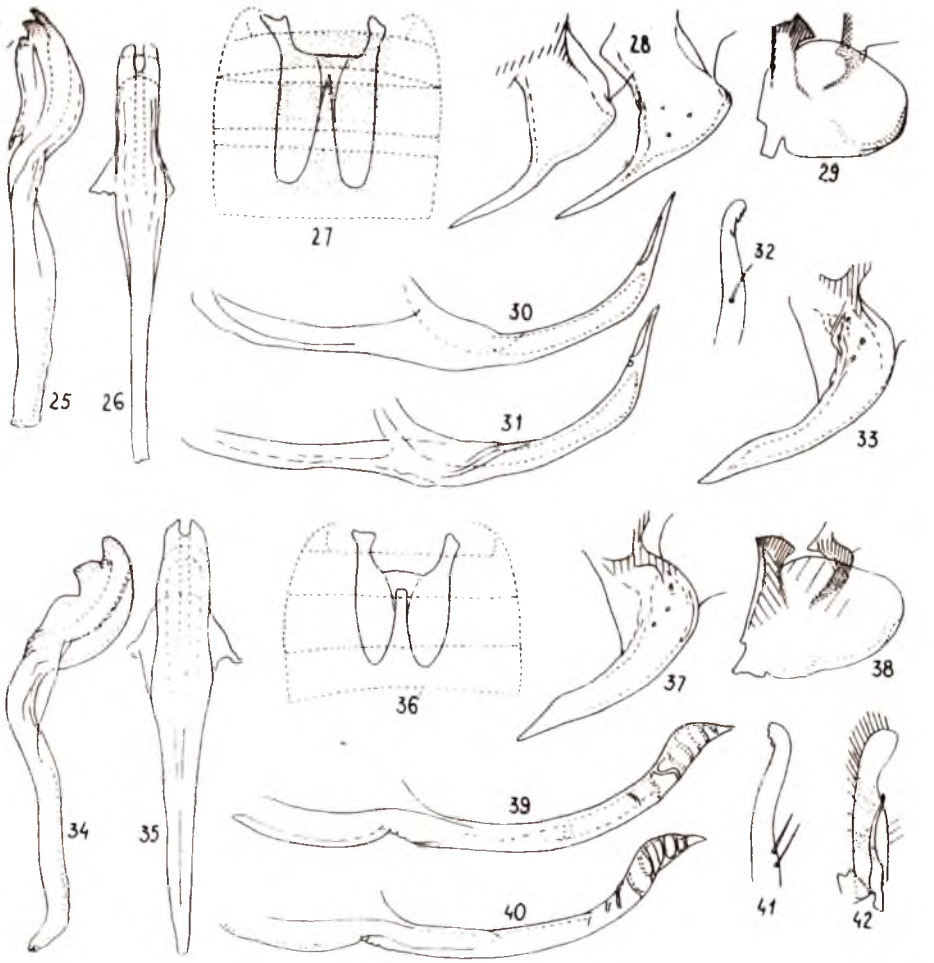
Length: ♂ 3.8 mm, ♀ 4. 0 mm.

Holotype ♂ INDIA: UTTAR PRADESH, Mussoorie, ex horse chestnut (*Aesculus indica*), 27. iv. 1975, coll. A. S. Sohi deposited at PAU, **Paratype** ♀,with same collection data as for holotype and deposited at the same place.

4. Alebroides montanus sp. nov. (Figs. 33–42)

Vertex slightly produced in the middle and rounded anteriorly. Ground colour light testaceous. Whitish pattern consists of a streak bordering coronal suture (the streak expands laterally near anterior margin of vertex forming semilunar patch), one central and two lateral patches at anterior margin of pronotum, broad central streak on scutum and a patch occupying almost whole scutellum. Eyes grey–testaceous. Forewing semitransparent, without markings; clavus slightly yellowish. Apex of valvulae dark brown.

Anal tube appendage large (Fig. 38), arcuate (Figs. 33, 37). Pygophore appendage sinuated at apex and ornamented with transverse ledges (Figs. 39, 40). Penis resembling that of *A. falcatus* sp. n. but extensions on its dorsal side broader (Figs. 34, 35). Abdominal apodemes quite short (Fig. 36); abdominal sclerites uniformly slightly infuscated.



Alebroides falcatus sp.n. (Figs. 25–32). 25–Penis, side view; 26–Penis, posterior view; 27—Abdominal apodemes; 28—Anal tube appendages; 29—Scheme of proportions and pigmentation of pygophore side and anal tube appendage; 30 & 31—Pygophore appendage; 32—Apical part of paramere.

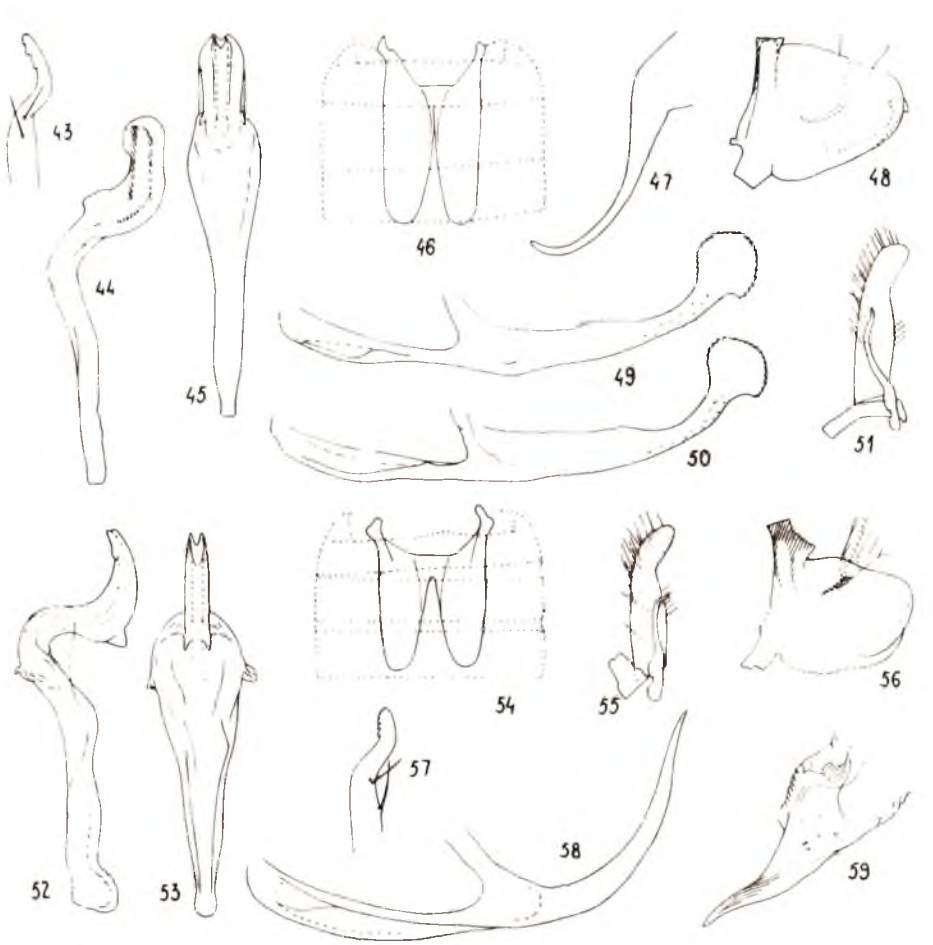
Alebroides montanus sp. n. (Figs. 33–42). 33—Anal tube appendage; 34—Penis, side view; 35–Penis; posterior view; 36—Abdominal apodemes; 37—Anal tube pappendage; 38—Scheme of proportions and pigmentation of pygophore side and anal tube appendage; 39 & 40—Pygophore appendage; 41—Apical part of paramere; 42—Proportions of subgenital plate, paramere, connective and ninth abdominal sternite.

Length: ♂ 3.6 mm, ♀ 3.9 mm.

Holotype ♂ INDIA: HIMACHAL PRADESH, Raison (Kulu), ex. *Chrysanthemum* sp., 4.x.1968, coll. A. S. Sohi, deposited at PAU, **Paratype** ♀ with same collection data as for holotype and deposited at the same place.

5. Alebroides clavatus sp. nov. (Figs. 43–51)

Vertex produced in the middle. Ground colour light yellowish-testaceous. A yellow roundish patch at apex of vertex which runs on to face. Eyes blackish. Whitish



Alebroides clavatus sp.n. (Figs. 43–51). 43—Apical part of paramere; 44—Penis, side view; 45—Penis, posterior view; 46—Abdominal apodemes; 47—Anal tube appendage; 48—Scheme of proportions and pigmentation of pygophore side and anal tube appendage; 49 & 50—Pygophore appendage; 51—Proportions of subgenital plate, paramere, connective and ninth abdominal sternite.

Alebroides luteus sp. n. (Figs. 52–59). 52—Penis, side view; 53—Penis, posterior view; 54—Abdominal apodemes; 55—Proportions of subgenital plate, paramere, connective and ninth abdominal sternite; 56—Scheme of proportions and pigmentation of pygophore side and anal tube appendage; 57—Apical part of paramere; 58—Pygophore appendage; 59—Anal tube appendage.

pattern consisting of irregularly shaped patches at sides of pronotum near eyes, central streak on scutum and a triangular patch at anterior margin of scutellum. Forewing semitransparent without markings. Apex of valvulae blackish. Abdomen and anal block not pigmented.

Anal tube appendage thin and long (Fig. 47). Pygophore appendages flattened at apex in the form of roundish plate with serrated margins (Figs. 49,50); there are small teeth in apical part of pygophore appendage. Penis stem tubular, angularly curved and rounded apically (Figs. 44, 45)

Length: ♂ 3.6 – 3.7 mm, ♀ 3.8 mm.

Holotype ♂ INDIA: UTTAR PRADESH, Dehra Dun, ex. *Michelia champaca* L., 28.iv.1975, Coll. A. S. Sohi deposited at PAU and **Paratype** ♂ with same collection data as for holotype and deposited at SMT and ♀ at PAU.

Alebroides clavatus can be distinguished from other species of *Alebroides* by the pygophore appendage which is flattened platelike with serrated margin at apex.

6. Alebroides luteus sp. nov. (Figs. 52–59)

Vertex of male slightly produced in the middle. Ground colour of upper side of head and thorax ochre–yellow, darker at apex of vertex. Frontoclypeus and anteclypeus ochre–yellow, sides of face whitish–testaceous. Whitish pattern visible as a small patch in the midline of scutum. Eyes blackish. Forewing semitransparent very light testaceous–whitish; apical cells and apical parts of longitudinal cells slightly infuscated. Margins of wing and apices of apical veins ochre–brownish. Abdominal sclerites infuscated.

Anal tube appendage short (Fig. 56), tapering, slightly sinuated, ornamented with minute longitudianal furrows (Fig. 59). Pygophore appendage arcuate, tapering, with no ornamentation (Fig. 58). Penis (Figs. 52, 53), resembling that of *A. nigroscutellatus* (Distant) but with distinct paired extensions at base of the stem on ventral margin. Abdominal apodemes quite short and broad (Fig. 54).

Length: ♂ 4.0 mm.

Holotype ♂ INDIA: Karnataka, 5–10 km SW of Mudigere, 2. vi. 1978, coll. C. A. Viraktamath, deposited at UAS.

The known species of *Alebroides* in India and Tibet may be separated by the following key except *Alebroides specturus* (Distant, 1918) which is known only by its female holotype from Kodaikanal, Tamil Nadu, India.

1. Pygophore appendage bifid ..... *A. nigroscutellatus* (Distant)
—Pygophore appendage not bifid 2

2. Penis with a pair of lateral appendages at base (Fig. 3) ..... *A. haedus* sp. nov.
—Penis without lateral appendages at base 3

3. Pygophore appendage with teeth subapically or flattened plate-like with serrated margins 4
—Pygophore appendage without teeth or serrated margins in apical part 5

4. Pygophore appendage thin, long, sinuated, ornamented with teeth subapically and pointed. (Figs. 21–24) ..... *A. fumosus* sp. nov.
—Pygophore appendage flattened, plate–like rounded at apex with serrated margins (Figs. 49, 50) ..... *A. clavatus* sp. nov.

5. Pygophore appendage sinuated at apex, ornamented with transverse ledges (Figs. 39, 40). Anal tube appendage caudally robust (Fig. 37) ..... *A. montanus* sp. nov.
— Pygophore appendage without transverse ledges; Anal tube appendage caudally thin 6

6. Atrial rim of aedeagus more than three times the width of aedeagal shaft in caudal view (Fig. 53), strongly sinuated in lateral view (Fig. 52) ..... *A. luteus* sp. nov.
—Atrial rim of aedeagus of same width as shaft (Fig. 26) weakly sinuated in lateral view (Fig. 25) ..... *A. falcatus* sp. nov.

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STUDIES ON ERIOPHYID MITES (ACARINA: ERIOPHYOIDEA) OF INDIA. IV. DESCRIPTION OF TWO NEW SPECIES OF *TEGOLOPHUS* KEIFER FROM WEST BENGAL

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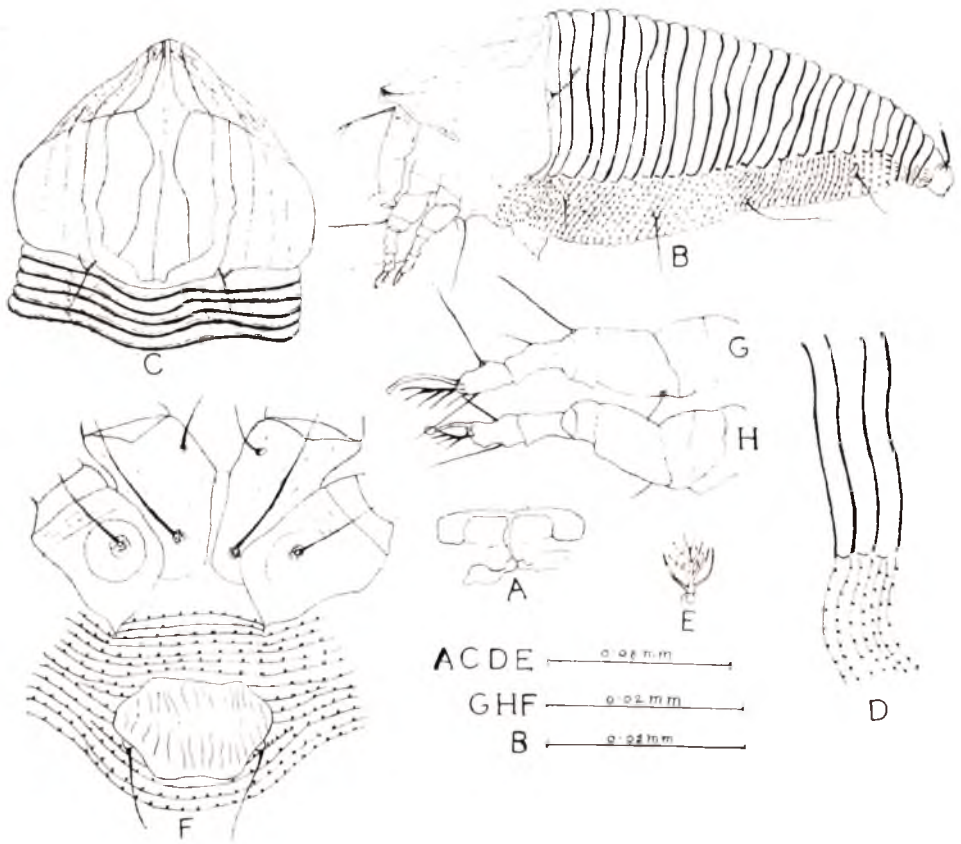
Two new species viz. *Tegolophus ficusi* **sp. nov. (Eriophyidae) infesting** *Ficus infectoria* **Rouxb. and** *Tegolophus nerii* **sp. nov. (Eriophyidae) infesting** *Nerium odorum* **Mill. are described from West Bengal, India. Relationship of these two species with the other known species of the genus, distribution and host-mite relationship have also been discussed.**

(*Key words :* **Acarina, eriophyids, taxonomy, morphology, new species, India**)

1. **Tegolophus ficusi,** sp. nov. (Figs. 1A–H)

Female: Body 115.24–160.8 long, 45.45–61.64 wide; fusiform; pale yellow in colour. Rostrum 25.44–27.56 long, projecting diagonally down; subapical seta 5.3–7.42 long. Shield 30.74–31.7 long and 36.04–41.34 wide; subtriangular with a short anterior lobe projecting over rostral base; shield design with a pattern of longitudinal lines; design on anterior lobe and lateral margin not clearly discernible; median line complete but faint on apical portion of the shield just below the anterior lobe; admedian line sinuate, orginating from the side of median line, diverge upto 0.3 portion from the anterior shield margin, then converge upto the middle of the shield and finally gradually diverge to meet the first submedian just anterior to the rear shield margin; submedian lines 6 in number of which only first and second are distinct; first submedian line originates from sides of anterior lobe, proceeds backwardly and divergently upto 0.3 portion of the shield anteriorly, then runs straight upto 0.16 portion of the shield from rear margin where it abruptly converges and meets with the first submedian of the other side just anterior to the rear shield margin; second submedian originates from lateral side of first submedian and runs parallel to it upto 0.16 portion of the shield from rear margin and then meets straight to the rear margin very close to dorsal tubercles; other submedian lines faint and parallel to the second one; dorsal tubercles present on the rear shield margin and 19.08 apart from each other; dorsal seta 4.24–6.36 long and backwardly directed. Foreleg 47.52–50.76 long from trochanter base; femur 10.8 long with a seta 11.8 long; patella 3.24–5.4 long, with a patellar seta 28.04–33.48 long; tibia 8.64 long with a tibial seta 6.48 long at 1/2; tarsus 5.4–7.56 long with two setae, each 17.0–21.6 long; claw 6.48–8.64 long, knobbed; feather claw simple, 4-rayed. Hindleg 41.04–44.28 long from trochanter base; femur 9.72–10.8 long with a seta 11.88–12.96 long; patella 3.24 long without patellar seta; tibia 5.4–6.48 long without tibial seta; tarsus 5.4–6.48 long with two setae, each 18.36–21.6 long; claw 5.4 long. Anterior coxae shortly contiguous, with no appreciable sternal ridge; anterior

Measurements of size are in μ, unless otherwise stated.

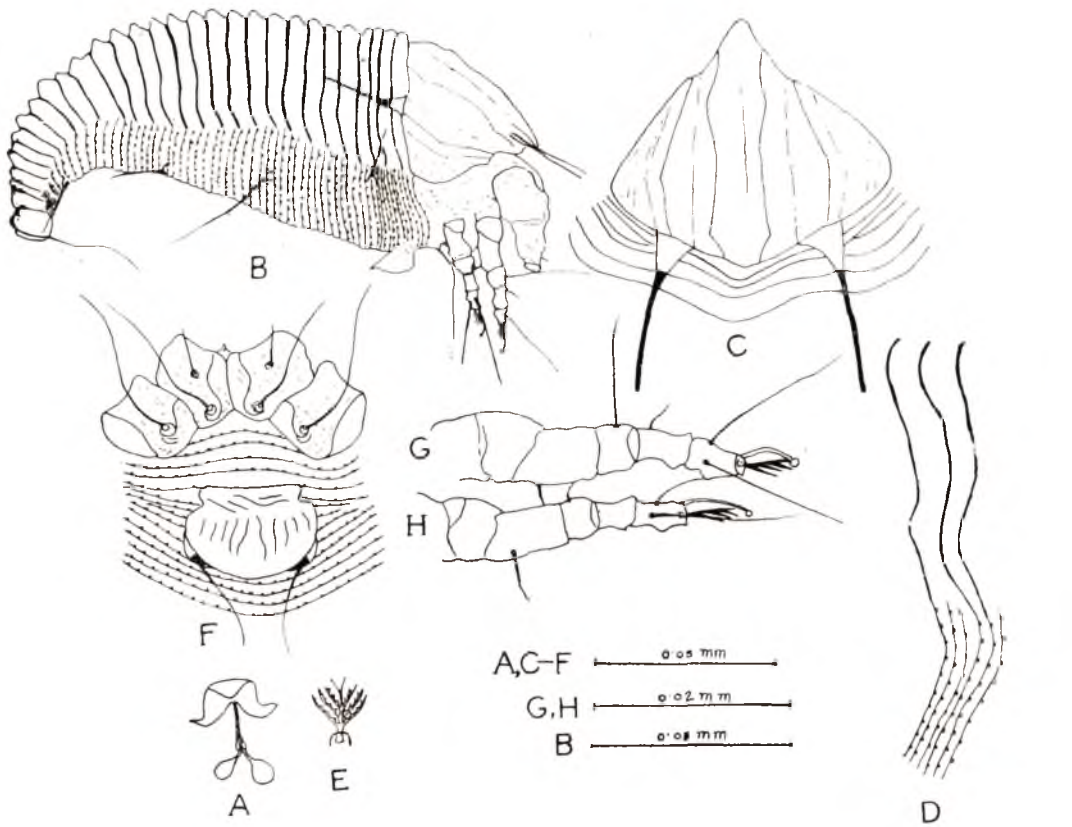


Figs. 1A – H. *Tegolophus ficusi*, sp. nov., Female : A – internal female genitalia; B – lateral view of mite; C – anterior dorsum of mite ; D – side view of skin structure; E – feather claw (Empodium); F – coxae and female genitalia; G – foreleg; H – second leg.

coxae with longitudinal dotted lines; posterior coxae ornamented with dotted transverse lines anteriorly; first coxal tubercles as further apart as second coxal tubercles and situated high up than second coxal tubercles; second coxal tubercles almost on the line across the third coxal tubercles; first coxal seta 10.6 long; second coxal seta 15.9 long; third coxal seta 35.92 long. Abdomen with about 28 tergites and 60 sternites, tergites with more conspicuous margins, with one very prominent mid-dorsal and two lateral ridges which are fading caudad; sternites with less conspicuous margins and with smaller microtubercles located on rear ring margin; last few sternites are microstriated; tergites nonmicrotuberculated; lateral seta 11.60–15.9 long, on about sternite 11; first ventral seta 27.0–37.1 long, on about sternite 23; second ventral seta 13.78–21.2 long, on about sternite 36; third ventral seta 13.78–21.2 long, on about sternite 52; caudal seta 42.4–46.64 long; accessory seta missing. Female genitalia 22.26–24.38 wide, 12.72 long; coverflap with about 16–17 longitudinal stripes; genital seta 12.72–15.9 long.

Male: Unknown.

Holotype: ♀, (On slide No. 71/22/76). INDIA: WEST BENGAL: Kalyani, 18.ix. 76 from *Ficus infectoria* Rouxb. (Morcaceae), (coll. S. Mondal).



Figs. 2A – H. *Tegolophus nerii*, sp. nov., Female : A – Internal female genitalia; B – lateral view of mite; C – anterior dorsum of mite; D – side view of skin structure; F – feather claw (Empodium); F – coxae and female genitalia; G – foreleg; H – second leg.

Paratypes: Many ♀ ♀, on 3 slides (Nos. 72/22/76 to 74/22/76), collection data as in the holotype; many ♀ ♀, on 1 slide (No.75/61/79), collected on 5.vii. 79 from same plant and locality.

Distribution: India: West Bengal.

The mites are vagrants on ventral surface of leaves. Due to infestation of the mites sometimes yellowish patches on the leaves were noticed, particularly when the population is maximum during October to December.

Remarks: In having broad tergites and narrow sternites along with 4-rayed feather claw and without microtubercles on tergites, *Tegolophus ficusi*, sp. nov. comes close to *Tegolophus australis* Keifer (1964); *Tegolophus artocarpi* Keiffer (1977), *Tegolophus hassani* Keifer (1959), *Tegolophus indica* Chakrabarti and Mondal (in press) and *Tegolophus nerii*, sp. nov. But from all these species except *nerii*, it differs by the nature of shield design. But *nerii* can be distinguished from *ficusi* by longer and more stout dorsal tubercles and setae, number of scoring on genital coverflap. However, from the nature of shield design, *ficusi*, sp. nov. also shows some similarities with *Tegolophus bambusae* Channa Basavanna (1966), but the present species remains

distinct from the latter by its 4–rayed feather claw.

2. Tegolophus nerii, sp. niv. (Figs: 2A–H)

Female: Body 128.64–174.4 long, 37.52–40.2 wide; fusiform; younger ones pinkish but mature ones yellowish pink. Rostrum 21.2–23.32 long, projecting diagonally down; sub-apical seta 5.3 long. Shield 14.54–23.38 long; 19.08–30.24 wide, sub-triangular; anterior lobe thin, short and acute; shield design with a pattern of longitudinal lines; median line straight, incomplete, very faint or almost absent on anterior .2 portion and posterior .28 portion of the shield; admedian lines complete, starting from the apex of anterior lobe, gradually diverging upto .32 portion of shield, then form an arc outwardly and finally converge to meet the rear margin; submedian lines three; first submedian straight, faint, arising from the base of anterior lobe run posteriorly and finally meet the rear margin; second and third submedian lines parallel to each other, arising from lateral margin of shield, diverge posterior upto .6 portion, then converge and finally meet the rear margin of shield. Dorsal tubercles placed on rear shield margin and 11.66–16.96 apart from each other; dorsal seta thick and 14.84–18.02 long, directed caudad. Foreleg 32.4–34.56 long from trochanter base; femur 10.8 long with seta 10.8–14.04 long; patella 4.32–5.4 long with seta 21.6 23.76 long; tibia 6.48–9.72 long with a tibial seta 5.4 long at 1/3; tarsus 7.56–8.64 long with two setae, each 21.6–23.76 long; claw 7.56–10.8 long, moderately knobbed; feather claw 4-rayed. Hindleg 28.08–30.24 long; femur 8.64–10.8 long with seta 10.8–15.12 long; patella 4.32 long with seta 10.8–15.12 long; patella 4.32 long, with seta 11.88 long; tibia 7.56 long without seta; tarsus 5.4–7.56 long with two setae, each 21.6 long; claw 7.56–10.8 long. Coxae broadly contiguous with a distinct sternal suture; both the coxae ornamented with scattered longitudinal and transverse lines; 1st coxal tubercles just below the anterior coxal approximation and 5.3 apart; second coxal tubercles just anterior to the first and second coxal junction and 4.24 apart, third coxal tubercle 21.2 apart; first coxal seta 9.72 long, second coxal seta 18.02 long; third coxal seta 21.2 long.

Abdomen with about 32–34 tergites and 58 sternites; tergites with more conspicuous margins, with one middorsal and two lateral ridges and all these ridges fading caudad; sternites with less conspicuous margins; microtubercles small, rounded, bead like, located on or close to rear sternal ring margin; last few sternites are microstriated, tergites nonmicrotuberculated. Lateral seta 7.42–11.66 long, on about sternite 11; first ventral seta 23.32–31.8 long, on about sternite 24; second ventral seta 7.42–10.6 long, on about sternite 38; 3rd ventral seta 12.72–19.08 long, on about sternite 52;caudal seta 42.4–47.7 long; accessory seta missing. Female genitalia 8.48–11.66 wide, 6.36.10.6 long; genital coverflap with about 10 longitudinal scoring; genital seta 10.6 – 12.72 long.

Male: Unknown.

Holotype: ♀, on slide (No. 76/62/79), INDIA: WEST BENGAL: Kalyani, 5. i. 79 from *Nerium odorum* Mill (Apocynaceae), (coll. S. Mondal).

Paratypes: Many ♀♀, on 10 slides (Nos. 77/62/79 to 86/62/79), collecton data as in the holotype; Many ♀♀ on 6 slides (Nos. 87/25/76 to 92/25/76) collected on 25.x.76 from the same plant and locality.

Distribution: India: West Bengal.

The mites were found lying within pits filled with hairy outgrowth on ventral

surface of leaves. Only one mite was found within a single pit. No other appreciable damage to the host plant was noticed.

Remark: This new species in having broad, non-microtuberculated tergites and 4-rayed feather claw, comes close to *Tegolophus artocarpi* Keifer (1977), *Tegolophus australis* Keifer (1964) *Tegolophus hassani* Keifer (1959), *Tegolophus indica* Chakrabarti and Mondal (in press) The relationships of *nerii*, sp. nov. with these species have been discussed under *Tegolophus ficusi*, sp. nov.

Acknowledgements :—The authors are thankful to Dr. H.H. Keifer, California for confirming the identity of *Tegolophus nerii*, sp. nov.; to the Head, Department of Zoology, University of Kalyani for laboratory facilities. Thanks are also due to the University Grants Commission, New Delhi, for financing the work through a grant-in-aid project.

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A NOTE ON *EUCELATORIA* SP. NEAR *ARMIGERA* (COQ.) (DIP., TACHINIDAE), IMPORTED FROM THE U. S. A., FOR TRIAL AGAINST *HELIOTHIS ARMIGERA* (HÜB.) (LEP., NOCTUIDAE) IN INDIA

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Eucelatoria* sp. near *armigera* (COQ.) parasitic on *Heliothis* spp. in the USA has been bred on *Heliothis armigera* in India. Notes on the development and laboratory multiplication of the tachinid are given.

In spite of repeated attempts made to control it, *Heliothis armigera* (HUB.) (Lep., Noctuidae) a cosmopolitan polyphagous pest, continues to be a serious threat to agriculture in India and other countries. The large complex of parasites present in India (RAO, 1968; ACHAN *et al.*, 1968) is unable to keep it under control.

Under a project of the Directorate of Plant Protection, Quarantine & Storage, Ministry of Agriculture & Irrigation, Go vt. of India, the CIBC Indian Station obtained from the USA a tachinid, *Eucelatoria* sp. near *armigera* (COQ.) parasitic on other *Heliothis* spp., to test on *H. armigera* in the laboratory and eventually in field trials.

In 1978 four airmail shipments were received from Mr. JAMES P. ROTH, Stoneville Quarantine Facility, U.S. Dept. of Agriculture, Stoneville, Mississippi. Because of delays in transist only one shipment reached Bangalore with live specimens. Of the 25 adults obtained 11 were females and 7 of them had apparently mated. A laboratory colony was built up with these using larvae of *H. armigera* bred on an artifical diet (NAGARKATTI & SATYA PRAKASH, 1974) and held at 26±1° C and 50–60% RH.

Life Cycle in the Laboratory

The males have a narrow and rather pointed triangular abdomen while females have a broad abdomen with somewhat rounded sides as in many other tachinids. The females have two pairs of fronto-orbital bristles pointing downward, which are absent in the males.

Males usually emerge first and mate with the females soon after the latter emerge. Mating may last 15 to 30 min. A male can mate with a second female about 30 min. after the first mating. Mating pairs are easily removed into glass vials and the females released in another cage on separation.

A single male may mate with up to 4 females per day.

The gestation period of mated females studied varied from 6 to 9 days. The females are strongly attracted to hosts from the ninth day after mating, preferring late 4th stage or early 5th stage larvae. The female approaches these, quickly punctures them with its larvipositor and injects the tiny maggots. Some haemolymph oozes

from the punctures and it may be fed upon by the same or a different female. In a defensive gesture the host larva often strikes at an approaching female in a bid to immobilize it by ejecting salivary fluid. It may bite its own body at the point of puncture, possibly as a response to the irritation caused by the larvipositing female.

Females lived up to a month when they were not provided with hosts to parasitise and for about two weeks with hosts available. Larviposition occurred until a day prior to the death of the female. In seven females, the number of progeny per individual varied from 20 to 40 but the uterus of dead specimens contained up to 13 eggs and 60 maggots.

Puparia were obtained 5–9 days after larviposition. The larval period was 5 days when 4 individuals developed per host and 9 days with 1.29 per host. The average was 6.14 days. The pupal stage lasted 8–9 days in males and 8–10 days in females.

As noted by ZISER *et al.* (1977) in studies on a *Eucelatoria* sp. there is a negative correlation between the number of parasites developing per host and the length of the larval period (Table 1).

Most of the larvae yielded one or two puparia each (Table 2).

TABLE 2. Number of *Eucelatoria* puparia obtained from host larvae after one larviposition.

No. of puparia	No. of hosts
1	15
2	12
3	3
4	1
Total 10	31
Mean per host	1.63

Laboratory multiplication

Fifty mated females are released for 30 min to 1 hr in a 30 cm cube cage with 20 fourth stage *Heliothis* larvae. After parasitisation, these larvae are replaced by fresh batches as long as the females continue to larviposit. The exposed larvae are placed singly with a piece of diet in 2.5 cm × 7.5 cm glass vials, which are plugged tightly with sterile cotton.

If the number of mated females available is less than 20, they can individually be provided with host larvae presented on a

TABLE 1. Number of *Eucelatoria* puparia per host and duration of larval period.

	Larval period (Days)						
	5	6	7	8	9		
Batch No.	No of pupaira/hosts					Total	Mean
1	26/6	42/12	11/8	9/6	5/4	93/36	2.58
2	8/3	13/5	14/11	1/1	1/1	37/21	1.76
3	12/3	12/3	26/9	1/1	1/1	52/17	3.06
4	26/6	21/9	5/3	7/3	2/1	61/22	2.77
Total	72/18	88/29	56/31	18/11	9/7	243/96	
Mean/host	4.00	3.03	1.81	1.64	1.29	2.53	

brush, one at a time. Since larviposition is rather qucik, one may easily get 10–15 parasitised larvae in 30 min.

After collection the puparia are washed in tap water to remove diet particles, rinsed in 1% aqueous solution of sodium hypochlorite and finally washed in distilled water three times. They are then held on a wet sponge in petri dishes in a cage until adult emergence.

Larvae should not be exposed to the parasite more than 2 or 3 times because superparasitism produces smallr, short- lived and less fecund progeny.

The specific identity of the *Eucelatoria* sp. we have studied is uncertain. ZISER *et al.* (1977) worked with a *Eucelatoria* species collected in Texas and referred to provisionally as *E. armigera* (COQUILLET), a well-known parasite of *Heliothis* spp. in the USA. *Eucelatoria* sp. had earlier been obtained by the CIBE Indian Station in 1969, bred on *H. armigera* and released in some areas, including one locality near Bangalore (RAO *et al.*, 1971).

JACKSON *et al.* (1969) stated that *E. armigera* did not complete development when it was reared at 35°C although emergence from *H. zea* (BODDIE) was almost normal at temperatures between 15°C and 30°C and from H. *virescens* (F) between 20°C and 32.2°C. The temperature tolerance of the present colony remains to be investigated.

BRYAN *et al.* (1972) working on a *Eucelatoria* sp. attacking *Heliothis* spp. in Arizona and western Texas (apparently the same as the present species) reported that when larvae of *H. virescens* were used a single female produced 144 progeny at 20°C and 198 at 30°C. The mean number/ female rose from 68.2 at 20°C to 112.9 at 30°C but dropped at higher temperatures. The lower progeny production in the present study was possibly due to the change over to a different host species.

Nucleus stocks have been supplied to the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad and to the Central Biological Control Stations of the Directorate of Plant Protection, Quarantine & Storage. Field releases are in progress.

Acknowledgement :—The authors are grateful to Mr. JAMES P. ROTH for supplying a nucleus culture of the *Eucelatoria* sp.

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BRIEF COMMUNICATION

RESIDUES OF SYSTEMIC INSECTICIDES USED FOR RICE PEST CONTROL IN RICE GRAIN AND STRAW

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(*Received 17 July 1979*)

When carbofuran, disulfoton and phorate granules were applied at the boot leaf stage, the former two insecticides at lower dosages did not leave residues in rice grain and straw above the tolerance limit, but their higher doses and phorate at both dosages left residues above the tolerance limits.

(*Key words*: **residue, rice, carbofuran, disulfoton, phorate**)

Application of systemic insecticides (granules) are being recommended in Kerala for the control of various rice pests even upto the boot leaf stage of the crop (ANON, 1978). But no information is available on the residues of these insecticides in rice grain and straw. Studies were hence undertaken to ascertain the residues of carbofuran, phorate and disulfoton in rice grain and straw, when applied as granules at the boot leaf stage of the crop. The experiments were conducted in clayey loam soils of the farm attached to the College of Agriculture, Vellayani, adopting randomised block design. The insecticides were applied in each treatment being replicated thrice. The experiment was done twice, but disulfoton was used in the second season only. Rice grain and straw well dried after harvest were analysed for the residues of insecticides adopting colorimetric procedure of GUPTA and DEWAN (1973) for carbofuran and of JAIN *et al.*, (1974) for phorate and disulfoton.

TABLE 1. Residues of some systemic insecticides in rice grain and straw, when applied as granules in soil at the boot leaf stage of the crop.

Insecticide	Dose (Kg ai ha)	Residues in ppm.				FDA tolerance level
		Grain		Straw		
		Expt. I	Expt. II	Expt. I	Expt. II	(ppm)
Carbofuran	0.5	ND	ND	0.35	0.47	0.5
	1.0	0.62	0.81	1.0	1.44	
Phorate	1.25	0.12	0.32	0.24	0.34	0.1
	2.50	0.38	0.65	0.85	1.1	
Disulfoton	1.00	..	0.49	..	0.68	0.75
	2.00	..	0.72	..	1.2	

Results (Table 1) show that carbofuran when used at 0.5 kg ai/ha did not leave any detectable residues in the grain and the residues (0.35 to 0.47) in the straw were found to be below the tolerance limit. When used at higher dose of 1 kg ai/ha the grain contained 0.62 to 0.81 and straw 1.0 to 1.44 ppm of the insecticide all of which were above tolerance limit. Phorate at both the doses of 1.25 and 2.5 kg ai/ha left residues in both the grain and straw above the tolerance limit of 0.1 ppm. In the case of disulfoton only the higher dose of 2 kg ai/ha left residues (1.2 ppm) in straw which alone was above tolerance limit of 0.75 ppm. In general there was a higher level of residues in the second experiment than the first. The residues of phorate in rice grain and straw reported from Tamil Nadu were much less than the residues detected in the present studies (RAJUKKANNU *et al.*, 1976).

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Books: NAYAR, K.K. (1973) *Elements in Insect Endocrinology*. Prentice Hall, India, 56pp. *Chapter in a book compiled and edited*: GILBERT, L. I. & D. S. KING (1973) Physiology of growth and development: Endocrine aspects, 249–370, *in: The Physiology of Insecta*, Vol. **1**, 2nd ed. (ed. ROCKSTEIN, M.), Academic Press, New York & London.

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